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ORIGINAL ARTICLES.

I.—Van Hise on the Division of the Pre-Cambrian.

By Alfred C. Lane, State Geologist of Michigan, U.S.A.

WHEN President Van Hise finished his address before the Geological Society of America last winter, which the Society has just issued, he leaned over benignly and glanced at Dr. Coleman, Professor Lawson, and myself, and said that while it was not customary to discuss the President's address he hoped in this case the custom would be waived, as he knew a number of members disagreed with him, and he felt they would have criticism of value to contribute. Whereupon ensued a most friendly but lively discussion, in which many took part. It has not been the custom of the Society to report such discussions, but I am sure that Van Hise will not object to see some of the points raised by the writer in print, as well as his Address.

The writer believes that the Keweenawan is Cambrian, and stands in somewhat the same relation to the Georgian and Acadian as does the Old Red Sandstone to the Devonian of the Eifel, or the Permian and Trias, with their lavas, to the Alpine facies of the same beds. This belief is shared with Professor Seaman, of the Michigan College of Mines, and N. H. Winchell, and we are as conversant with the facts as any.

It is true no fossils have been found, and that the extreme Upper Cambrian where it abuts against the Lower Keweenawan series overlaps it unconformably. But if, as Leith suggests, it is a land formation, that is exactly what would be expected. It is, however, a moot question of fact, upon which probabilities must be balanced, and I believe that in the forthcoming monograph by Van Hise and Leith on the Lake Superior region both sides of the question will be fairly put forth, and they will doubtless agree with the writer in saying that it would be dangerous, in making estimates of the age of the earth, to assign to this series of lavas and conglomerates a thickness of 50,000 feet or anything like the age-value of a series of limestones and shales. This was recently and quite pardonably done by a writer in the Geological Magazine, who was not acquainted with the local facts. It will be much wiser in such estimates to count it as part of the Cambrian. There are, however, some other questions

of word usage not requiring local knowledge, but rather matters of English style, upon which one may rightly appeal to an English audience for a fair and intelligent judgment, in regard to which the writer differs from Van Hise.

In the first place, while Van Hise no longer absolutely restricts the Archæan to non-klastics, he does restrict it to pre-Huronian.[1] But, as he clearly states, the term Archæan was introduced by Dana to avoid the implication as to life of the term Azoic (and Eozoic) for all the pre-Cambrian rocks, and was divided by Dana into two groups, the Huronian and Laurentian. The excuse of Van Hise for thus modifying the definition and denotation of the term and its connotation is that to include "both pre-Cambrian groups under one name would result in making two groups of rock to appear to be alike when, as a matter of fact, they are radically different"—the same objection that some feel against using the term Algonkian to include Keweenawan and Huronian.

While he thinks that in so doing he carries out the "essential intent" of Dana, the writer cannot agree with him. Nor did Dana himself. In view of the fact that Van Hise has to use the synonym pre-Cambrian fifty-three times in twenty-six pages, there would appear some justification for those geologists who prefer to employ the term in the original sense. It is not so bad if one does not mind capitals in the midst of a word to write pre-Cambrian, but if one needs to refer to time since, it is certainly clumsier to say post-pre-Cambrian than post-Archæan.[2]

But are they really so "radically different"? Van Hise has shifted his definition. It is no longer the distinction between klastic or not. He makes it very clear that it is not 'zoic,' and a lack of clarity exists, which, as it is absent from the style of this clear and forceful writer, seems rather imaginary. An extra widespread and important unconformity between them, a greater proportion of normal sediments in the later division or Huronian, and very great difficulty in applying ordinary stratigraphic methods to the earlier pre-Cambrian —these appear to be the bases of division. But it is clear, it is indeed emphasized by Van Hise, that division on such lines is essentially local, unless one could show some reason why all over the earth at the same time there should be a great unconformity, as when the moon went off.

It would seem to the writer on *such grounds* impossible to be sure, for instance, that the Kona Dolomite of the lowest Huronian might not be the equivalent of the Grenville Limestone of the Upper Laurentian.

It is unfortunate that in a paper devoted to discussing the division of the pre-Cambrian, by an oversight Van Hise should forget to mention the early thesis of the eminent geologist Credner on this subject,[3] while he pays so cordial a tribute to Pumpelly and Marvine.

[1] If we remove the Keweenawan to the Cambrian, the Algonkian becomes a synonym, around Lake Superior at least, for Huronian.

[2] Cf. Becker in the same Bull. Geol. Soc. Amer., 19, p. 128.

[3] "Die Gliederung der eozoischen (vorsilurischen) Formationsgruppe Nord Amerikas": Zeitsch. für die Ges. Wiss., 1868, xxxii, pp. 353–405.

with whom Credner was associated. This rather rare paper was probably not at his hand. Credner was one of the earliest writers to advocate substantially the dual division of Van Hise, though with other nomenclature, thus:—

Eozoic { Huronian. / Laurentian.

It strikes the author as a pretty good nomenclature, well worthy a few moments discussion by Van Hise.

It seems to him, however, and he does not wish this paper to be purely critical, that there will be such a dual division, on a sound philosophic and 'zoic' basis, though not exactly on the line laid down by Van Hise.

There has been much discussion of late of desert sedimentation, by Walther, W. M. Davis, Barrell, Huntington, and others. It seems to the writer that many of the peculiarities of the desert are due, not to the arid climate *per se*, but to the fact that it is devoid of vegetation. This we now find practically only in arid lands, but before the earth was clothed with verdure, or moss or lichen existed, the land must have been bare, and even though the climate were wet the sedimentation must have been very different. In particular, without the organic acids there must have been little chemical denudation by organic acids and carbon dioxide. This had an effect in two ways. In the first place, the streams contained little carbonates and yielded little to the ocean. In the second place, the sediments formed by disintegration of the rocks, which mechanically is much more active when not protected by vegetation, must have been much richer in the soluble bases, which would otherwise have been removed by the organic acids. In this way were produced the ancestors of the arkoses, greywackes, and sedimentary gneisses and schists. Thus the peculiar character of the early sediments upon which Van Hise comments may have a direct 'zoic' meaning. Nor is this the whole story. The subtraction of organic additions and disintegration leaves the other kind of chemical activity more important—the volcanic exhalations, in which there is reason to believe chlorine and sulphur emanations were prominent, would still exist, and in fact there was volcanic activity and agglomerates on a large scale. These acid radicals would, however, tend to carry off the iron to the sea and not precipitate it as the carbonate radical does. We should, therefore, have had in the Azoic ocean at the end an accumulation of chlorides of calcium, iron, and other bases, and its sediments composed of volcanic agglomerates and conglomerates, and mechanical sediments, like arkoses and gneisses and mica-schists, differing but slightly from the associated igneous rocks. Now this is the character of the oldest rocks, the Keewatin series, and analyses indicate that the early ocean was relatively a solution of calcium chloride, while Quinton's very plausible theory, especially with the modifications suggested by the writer,[1] implies a relatively fresh ocean. Such, then, would be the Azoic, the early part of the pre-Cambrian.

[1] "The Early Surroundings of Life," Science, 1907, vol. xxvi, p. 129; "The Chemical Evolution of the Ocean," Journal of Geology, 1906, vol. xiv, p. 205; Bull. Geol. Soc. Amer., 1907, vol. xvii, p. 691.

When life came, perhaps waiting until enough carbon for its existence had accumulated in the ocean from volcanic sources, there would be a gradual development of more ordinary sediments, and river waters, with sodium carbonate and silicate in solution, such as now drain granite areas, would begin the precipitation of calcium chloride as calcium carbonate and accumulation of sodium chloride, which has been the dominant factor in oceanic chemical evolution. Very promptly, however (this theory is due to Leith), the sodium silicate would react upon the chloride of iron, precipitating the silica and iron as iron oxide and chert, mixed perhaps with carbonates. I have recently seen an ideal specimen of such a rock from a 2,000 feet drill-hole in the deep continuation of the Mesabi range. Thus we have the cherty iron members, which are so universal a feature of the various Huronian series, and we also have sodium chloride left in solution.

During the period of the dawn of life there would then be as characteristic the chemical precipitation of the carbonates of calcium, iron, magnesium, etc., and of chert and iron oxides, from chloride or sulphate solutions.[1] Decaying organic matter would also produce the black muds from which come the graphitic slates. The other sediments would approach gradually the customary types.

Chamberlin and Salisbury have touched upon the abnormal character of the pre-Cambrian sediments, though not using it as a basis of subdivision.

During all this time, however, the ocean remained relatively fresh and unfavourable to the secretion of shells, and the rapid evolution of life into various branches of the animal kingdom went on without hard parts, and without a body-cavity closed from the oceanic vital medium. But with the steady accumulation of salts in the ocean, its waters reached and passed the physiological optimum of eight parts per thousand. Numerous different branches responded to this change of environment for the worse by secreting calcium carbonate or phosphate, which were already present to saturation, at first as a pure physiological or pathological necessity like renal calculi. But it at once was found to be of immense value as a skeletal support and protection. Only in some such way does it appear to the writer that we can account for the appearance of hard parts in numerous branches of the animal kingdom at about the same time. It must be due to a general reaction to some general change of environment, and this particular change, supported as it is by analyses of connate waters and the general drift of chemical evolution of the ocean, as well as by the physiological evidence so acutely marshalled by Quinton, is by far the most plausible. This event marks practically the beginning of the Cambrian. The classification which the writer would suggest as probably that of the future is tabulated below. The connotation is very different from that of Van Hise, but in denotation of application the only changes needed will be to remove perhaps a small portion of that generally referred to as Keewatin, as well as the Grenville Limestone and associated beds, from the Azoic.

[1] Judging from the results of analyses of connate waters, the writer leans to chlorides.

SUGGESTED SUBDIVISION OF THE PRE-CAMBRIAN.

Life Eras.	Life.	Ocean.	Land.	Formations.
Palæozoic.	Animals with hard parts and body-cavity closed; land animals begin.	Growing salter, with Na Cl increasing.	Ordinary sediments and fossils.	Cambrian (Keweenawan).
		Total solids 8 per thousand.		
		Na Cl = 1 : 12 +		
Eozoic or Proterozoic.	Life important, abundant, rapidly increasing, and differentiating, vegetable life on land. Sea animals without hard parts and probably without a closed body-cavity.	Fresh, perhaps slightly acid with volcanic emanations, unfavourable to lime secretion, but precipitating it with iron and magnesia by reaction of chlorides (or sulphates) with sodium carbonate or silicate, and perhaps by vegetation like *Chara*.	Land clothed with low vegetation, chemical composition of streams like those of the Laurentian Highlands to-day; mechanical erosion becomes less, chemical more, important.	Neo-Huronian (Animikie).
				Mio-Huronian.
			Sediments: chert, iron oxides, volcanic agglomerates, greywackes, precipitated dolomites, also the ordinary mechanical sediments and black slates.	Eo-Huronian.
				Logan's Upper Laurentian.
	Animal life begins.	Total solids very low.	Fossils only preserved as imprints.	
		Na Cl = 1 : 60 +		
Azoic.	Life absent or local and insignificant, probably a good part of the time conditions such as would make its wide distribution impossible.	Fresh, unfavourable to life, acid with volcanic emanations; chlorides accumulate. Sulphates reduced to sulphides by ferrous iron (?) from basic rocks, hydrocarbons accumulate.	River-water fresh, nearly free from carbonates, with little tendency to leach out the alkalies exclusively. Surface uncovered, exposed to very rapid mechanical action.	(Most of the) Keewatin, Greenstone schists, gneisses (Coutchiching, if it exists, as the writer does not think).
		Resultant sediments mechanical, not unlike in chemical composition to the rocks from which they were derived, no organic rocks (like black slates), no leached or chemically deposited iron ore, no true massive stratified dolomites, volcanic rocks abundant.		

Archæozoic or Proterozoic. Dana's Archæan Pre-Cambrian.

The question naturally arises with regard to the above table, which of the above characteristics shall be taken as determinative in drawing the lines? The writer may be prejudiced by his studies of connate waters, but he feels very strongly that a marked point in the chemical evolution of the ocean, which must be practically nearly universal and coeval, makes the best of dividing lines. So he would put the beginning of the Cambrian at the time the concentration of the ocean passed the physiological optimum (somewhere between six and eight parts per thousand), and the secretion of hard parts by living organisms began, and he would put the beginning of the age previous when the water supplied to the ocean became alkaline, and hence the accumulation of chlorides of lime, magnesia, and iron was checked, and he believes that was due to the first great extension of living vegetation over the surface of the land. He does not believe it purely accidental that massive beds of dolomite, of chert and iron, i.e. jaspilite, and of black slate appear in about the same series.

II.—On the Dentition of the Palate in the South African Fossil Reptile Genus *Cynognathus*.

By Prof. H. G. Seeley, F.R.S., F.G.S., King's College, London.

(PLATE XXIV.)

THE Cynodont reptilia from the Lower Karroo rocks of South Africa, characterized by relatively large incisors and relatively small, sharp-pointed, molar teeth, were grouped under the type genus *Lycosaurus* as Lycosauria. The removal of matrix from the palate of *Ælurosaurus* showed that in one member of the group at least the palate carries patches of teeth, each of which has the form of a small blunt flattened cone. From the fact that no Cynodont skull is available in which the mandible is free from the head, the nature of the palatal dentition is imperfectly known.

Of the new Cynodont reptilia obtained by myself from the Upper Karroo rocks in 1889, the most complete were species of *Cynognathus* (Phil. Trans. Royal Soc., B, 1895, p. 59). But these specimens, with relatively large denticulated molar teeth, all have the mandible closed upon the skull, so that the anterior part of the palate is not displayed.

In *Cynognathus crateronotus* (op. cit., fig. 9, p. 83) the palatine bones arch over the palato-nares, but as they extend backward laterally each appears to be twisted over, with a lateral bulge, to make the walls of the palato-nares behind the hard palate. The mandibular symphysis obscures the front of the palate, but it only extends posteriorly as far as the maxillary canines. No teeth were exposed upon the maxillary plates of the palate. The matrix is so intractable and the bones so friable in the figured species *C. Berryi* that no attempt can be made to expose the palate with the chisel. In this species the extremity of the snout is lost. But the weathered nasal chamber shows a vertical median plate of bone (op. cit., fig. 24, p. 124) which appears to enter into the palate, rising for some distance into the nasal chamber, where it is flanked by thin, curved plates which may represent turbinal bones. It is less than $\frac{1}{10}$ inch wide, separated

from the flat maxillary bones of the palate by vertical sutures. It appears to afford evidence that the premaxillary bones enter into the front of the hard palate, and are free from palatal teeth. The skull of *C. platyceps* (op. cit., fig. 30, p. 139) adds nothing to our knowledge of the anterior part of the palate. Only the posterior part of the median suture is exposed, dividing the concave channel of the hard palate. There are no indications of palatal teeth; but this is no evidence that such teeth did not exist, for such structures are not likely to be found unless there is reason to look for them, and they would be easily removed by the chisel without detection.

I am indebted to the generous co-operation and enthusiasm of Dr. D. R. Kannemeyer for a fragment of a right maxillary bone from Wonderboom, which has almost exactly the size, form, and aspect of the corresponding region of the jaw of *Cynognathus crateronotus*. I have removed the matrix in the Geological Laboratory of King's College, London; and the bone (Plate XXIV) shows both externally (Fig. 2) and on the palate (Fig. 1) characteristics seen in no other figured example, but confirmed by other evidence in my hands.

The maxillary bone is separated by sutures of a squamose type from the nasal bones above and the premaxillary bones in front. The vertical premaxillary sutural surface is $1\frac{2}{10}$ inch deep, flattened, $\frac{4}{10}$ inch wide, and is limited posteriorly by the large cavity for the mandibular canine, which is excavated in the skull for $1\frac{1}{4}$ inch, and made partly by the maxillary, partly by the premaxillary bone.

Above the premaxillary suture in front is a small, smooth, rounded notch, which appears to be the hinder angle of the anterior narine, between the premaxillary and nasal bones.

The maxillary bone is limited at the upper border by the strong, vertical, squamous suture with the nasal bone. This sutural surface seen on the inner aspect of the specimen is half an inch deep in front, with the depth increasing as it extends backward. The curved contour-line of junction is indicated by the maxillary bone being 2 inches deep in front and about $3\frac{1}{2}$ inches in depth at the vertical fracture behind.

Externally (Pl. XXIV, Fig. 2) the anterior and larger part of the bone is convex, both from front to back and from above downward. This convexity is only modified by a slight, shallow, wide, longitudinal concavity, extending backward from below the nasal suture towards the direction of the prefrontal bone. But inferiorly the bone contracts in width behind the canine tooth, defining the bulbous snout, so that the lower and hinder external surface is concave.

The alveolar border behind the canine tooth, seen from the side, is straight or concave in length, while in front it recedes laterally upward towards the premaxillary suture, being convex above the maxillary canine and concave in front of the mandibular canine.

The posterior fracture passes through a conspicuous, circular, pre-orbital pit in the middle depth of the bone, situated above the fourth or fifth molar tooth. It corresponds in position exactly with the sub-orbital or middle foramen seen in the maxillary bone of the type-specimen of *Cynognathus crateronotus* (op. cit., p. 72, fig. 5). Now that the matrix is removed (Pl. XXIV, Fig. 2), the fossil shows externally at $\frac{9}{10}$ inch above the alveolar border a linear succession

of four foramina corresponding in position with the bases of the roots of molar teeth. There are also three or four smaller foramina further forward, nearer the alveolar border, which have no obvious relation to dental nutrition. There are several small, scattered, vascular foramina above the diastema in advance of the maxillary canine tooth.

In the original description the external surface of the anterior bulbous part of the maxillary bone of *C. crateronotus* is only referred to as being irregular with undulating depressions and convexities. In *C. Berryi* the bone shows a finely pitted ornament of a radiating sub-crocodilian type, in advance of the sub-orbital foramen.

In this maxillary bone the ornament (Pl. XXIV, Fig. 2) consists of close-set, small bosses with concave summit-surfaces, surrounded by depressions, which are divided into groups by sub-parallel winding longitudinal canals, with vertical connecting branches. Two or three of these sinuous, vascular channels close together are below the sub-orbital foramen, one is level with it, two are above and wider apart. Some short oblique canals descend upon the convexity of the root of the canine tooth, giving that part of the bone a fluted or folded aspect. The pitted ornament is most dense in the central area above the imbedded root of the canine tooth, and is less distinct downward, forward, and upward to the nasal suture.

The maxillary bone is exceptionally strong, averaging $\frac{8}{10}$ of an inch thick at the posterior fracture, and thinning away in front and above to the squamous premaxillary and nasal edges. Its transverse width on the palate at the canine tooth is $1\frac{8}{10}$ inch, giving the snout a width of about $3\frac{1}{2}$ inches by allowing for the left maxillary.

The internal surface of the bone above the palate and below the wrinkled sutural surface for the nasal bone is smooth, convex over the oblique root of the canine tooth, and excavated concavely below and behind it, owing to the inward extension of the maxillary plate which forms the palate.

The palatal surface of the maxillary bone contracts in width behind the canine (Pl. XXIV, Fig. 1). It is $1\frac{1}{2}$ inch wide over the first molar tooth, and about $1\frac{8}{10}$ wide at the posterior fracture. Anteriorly the palatal width decreases towards the premaxillary suture.

The crowns of all the teeth, canine and molars, are broken off level with the alveolar margin of the jaw, so that no trace is preserved of the characteristic forms of the molars of *Cynognathus*. The base of the crown of the canine is slightly ovate, compressed on the inner hinder side, implanted obliquely, directed forward, downward, and outward. It is 1 inch from front to back and $\frac{7}{10}$ inch transversely. The fracture shows a small pulp cavity.

Behind the canine is the triangular area which indicates the remnant of the base of the milk or first canine, which was removed by absorption (Pl. XXIV, Fig. 1). That tooth-fragment is obscure, but may have been fractured during the life of the animal. The absence of a tooth in this position gives the jaw laterally the aspect of having a small false diastema.

The molar teeth extend backward in a line with the inner border of the canine tooth. They vary in size, but the oval roots of the first five are contained in a length of $1\frac{8}{10}$ inch. The first has a sharp

Maxillary dentition and snout-sculpture, *Cyamspatulus costeroanatus*.

cutting-edge in front, and is rather larger than the second. The third is longitudinally oval, and the fourth and fifth are more elongated, with a laterally compressed aspect. All are crowded into close contact.

The fracture passes through the root of the sixth tooth, which is an inch deep in the jaw, and shows the anterior border of a pulp cavity, which appears to be narrow, but is closed at the base. The root is $\frac{3}{16}$ inch wide, slightly curved inward, and its termination shows a slight notch, too slight to suggest root tubercles.

The palatal surface (Pl. XXIV, Fig. 1) comprises three areas: first, the external dentigerous border described; secondly, a middle smooth longitudinal channel; and thirdly, an inner longitudinal dental armature.

The middle concavity is wide and inclined on the outer part, narrow and steep towards the inner teeth. The more flattened part is marked towards the alveolar border with a fine, impressed, longitudinal, vascular line almost like a suture, but there is no trace of sutural separation on the posterior fracture. This smooth area ascends in front of the canine tooth into the pit for the mandibular canine, by a continuous rounded surface. The mandibular canine pit is apparently triangular, $1\frac{1}{2}$ inch deep, convex over the inner side of the canine, concave on the external lateral border, and internally it is obscured a little towards the palatal armature by crushing, but was probably concave.

The smooth palatal surface is about $\frac{3}{4}$ inch wide behind the canine tooth where widest, and extends backward with a uniform width of about half an inch. Opposite the fourth and fifth molars it develops a small longitudinal ridge, and on the inner side, next the palatal armature, there is a deep narrow groove, which is prolonged upward as a cleft or canal as though the palatal plate of the maxillary had originally been a distinct ossification from the dentary plate.

The internal portion of the palate, which carries a dental armature adapted for crushing food, is wedge-shaped in form, narrow in front between the canine teeth, widening posteriorly to fully half an inch at the posterior fracture. On the inner margin it forms a strong dental ridge, but the rest of the plate is inclined outward, so that its thickness diminishes towards the smooth channel already referred to. This armature has a certain resemblance to the tooth-plates of *Hyperodapedon* carried upon the maxillary bones and upon the parallel palatine bones. But these tooth-plates are supported upon the maxillary bone only, like the separate teeth of Endothiodonts and Lycosaurians. This triangular dental wedge is a little injured by transverse fractures, made during movements of the rock, which have bent it slightly outward at both the anterior and posterior ends. The tooth-plates are supported upon a very thin palatal expansion of the maxillary bone. With this the crushing toothed armature unites without visible suture. But a small dental plate anterior to the others was not anchylosed, and is lost. Its empty socket (Pl. XXIV, Fig. 1, E.S.) next the vacuity for the mandibular canine tooth shows that it had a basal and internal support, and rested against the dental plate behind. The premaxillary bones may have extended between and above this region of the armature, but there is no evidence of those bones preserved, unless it be in the anterior internal thickening of the maxillary bone

as a wedge which thins as it extends backward supporting the palatal armature. There is no doubt that the tooth-plates met each other in the median line of the palate without any sutural union or connection between the contiguous maxillary bones other than the premaxillary bones may have given.

The inner median surface of the dental plate shows no indication of sutural separation from the opposite maxillary bone, except in the smooth base of the empty anterior socket.

This inner surface of the plate is even, flat, with a straight base-line, prominent above the contiguous maxillary bone, curving upward as it extends forward. It is sub-parallel to the palatal dental crest; the depth of the dental plate is half an inch behind and $\frac{3}{10}$ inch in front. This internal surface shines as though covered with a film of enamel. It is finely pitted along its extent. It is roughened with the contours of constituent denticles, of which there are more than a dozen in a length of 2 inches, all welded together. Some are triangular, and their points do not reach the palatal surface, while the denticles between them, with exposed crowns, have ovate surface contours on the summit-ridge of the palate. The appearance is that of a mass of teeth densely packed in osseous union or cement.

The fractured posterior surface is less clear than might have been expected. It shows that the denticles are parallel to the inner surface and to each other. They are vertical and form about six rows, so that the individual teeth of the successive rows become shorter as they extend outward from the median line in harmony with the incline of the dental plate. The obscure sections appear to be narrow and cylindrical, but the teeth are probably of a flattened ovate form in section, like the low crowns on the palate.

On the palatal surface the denticles are arranged in parallel rows (Pl. XXIV, Fig. 1, P.T.), rising inward in successive tiers one behind another. The short, low crowns have an ill-defined appearance of being also arranged in rows which extend obliquely outward and backward. Each crown is longitudinally ovate. They vary in size and elevation and distance apart. Generally the convex surface carries one or two raised lines and a few granules which show no definite plan of arrangement. The rows of denticles become fewer as they extend forward, and at the front of the principal plate are reduced to three rows. At this point a fracture occurs, which appears to mark a second dental plate, in which all the rows are gathered up into one compressed elevated tooth-mass, about half an inch long. Its constituent denticles appear to be worn with use; they are close set, small, ovate, oblique, and comprise two parallel rows. The narrow missing tooth was shorter and may have had a similar structure.

Having this remarkable armature on the maxillary bones, it was important to re-examine the skull of *Cynognathus crateronotus* in the Natural History Museum, and Mr. Richard Hall has so far removed the matrix from the symphysial region of the mandible, with the approval of Dr. A. Smith Woodward, as to demonstrate the presence of teeth of a similar kind upon the maxillary plate of the palate, and prove that this dental armature is one of the generic characters of *Cynognathus*.

The mammalian aspect of the alveolar dentition in *Cynognathus* may have drawn attention away from the obvious resemblances between the Lycosauria with prehensile molars and the Cynognathia with cutting molar teeth. But the teeth upon the maxillary plate not only emphasise a close affinity between these divisions of the Cynodontia, but appear to indicate wider affinities of the Cynodontia with other Anomodont reptilia. Thus in *Pareiasaurus* the palate carries parallel rows of slender prehensile teeth as well as the alveolar teeth. And in the Endothiodontia the palatal dentition is fully developed though the alveolar teeth are absent. In all these types the palatal teeth preserve their individual separation from each other, and it is only in *Hyperodapedon* that any parallel is found to the way in which the palatal plate is formed in *Cynognathus*.

The posterior widening of the palatal armature by which the crowns of the denticles become separated from each other I regard as a specific character only, for in the badly preserved and crushed skull of another species the posterior expansion of the dental plate appears to be absent. If that specimen should eventually have the matrix removed sufficiently to be figured, it will show that the posterior nares were margined in this genus by broad, flattened, dental bands upon the palatine bones which have the aspect of crushing teeth, wrinkled transversely in front and somewhat tuberculate behind, but quite unworn, as might have been anticipated. The palatine dental plates can only be uncovered with the needle, and would be lost under the chisel.

EXPLANATION OF PLATE XXIV.

Maxillary dentition and snout-sculpture of *Cynognathus crateronotus*.

Fig. 1.—Palatal aspect of the right maxillary bone, showing A.T., the line of alveolar teeth, and the large canine tooth, all broken off in their sockets, also the pit for the mandibular canine tooth in front. Internal to these teeth is the smooth concave tract of the palate. P.T. indicates the long wedge of consolidated palatal teeth, narrowing in front. The crowns of these teeth have been touched with white to throw them into more distinct relief in the photograph. E.S. is the empty socket from which a tooth appears to have been lost.

Fig. 2.—External surface of the anterior half of the maxillary bone, showing the pitted and vascular sculpture. The notch in front indicates the back of the narine. Above is the line of suture with the nasal bone. The base of the canine tooth is visible on the convex middle part of the alveolar border.

The figures are of natural size.

III.—On a large Cirripede belonging to the genus *Loricula*, from the Middle Chalk (Turonian), Cuxton, near Rochester, Kent.

By Henry Woodward, LL.D., F.R.S., F.G.S., V.P.Z.S.

More than sixty years ago Mr. G. B. Sowerby, jun., described and figured a unique specimen of a remarkable fossil Cirripede from the Chalk of Kent which he named *Loricula pulchella*.[1] It was obtained by Mr. N. T. Wetherell, F.G.S., of Highgate, and was subsequently acquired with that gentleman's collection by the British Museum (Natural History). Mr. Wetherell's *Loricula* was again

[1] G. B. Sowerby, jun.: Ann. Nat. Hist., 1843, vol. xii, p. 260.

described and figured by Charles Darwin in his "Monograph on the Fossil Lepadidæ or Pedunculated Cirripedes of Great Britain." [1]

About thirty years ago I found a second specimen of *Loricula pulchella*, or, I ought rather to say, the *intaglio* or hollow impression left by the upper surface of its valves, upon the shell of an *Ostræa* from the Chalk, which had evidently grown upon the *Loricula*, and thus preserved on the outside of its attached valves a perfect facsimile of the upper surface of the Cirripede. At that time I made a cast in *relievo* from this natural mould and placed the two side by side in the British Museum case next to Mr. Wetherell's type-specimen. (See Gallery viii, Geology, Invertebrata, T. Case 22.)

Professor K. A. von Zittel [2] has described a *Loricula* (*L. lævissima*) from the Senonian (Upper Chalk) of Dülmen, Westphalia, and Professor W. Dames [3] *Loricula Syriaca* from the Cenomanian (Lower Chalk) of the Lebanon.

In 1887 Professor Dr. Anton Fritsch [4] described and figured a number of *Loriculæ* from the Turonian (Middle Chalk) of Weissenberg, Bohemia, which he referred to Sowerby's *L. pulchella*, making two varieties, *L. pulchella*, var. *gigas*, and *L. pulchella*, var. *minor*, both of which were found attached to specimens of *Ammonites peramplus* and *Ammonites Woolgari*.

Dr. J. F. Whiteaves, in 1889, described a species of *Loricula* under the name of *L. canadensis*, Whit., from the Cretaceous, Fort Benton group, south of Duck River, Township 34, Range 23 W. (See Cret. Foss. British Columbia, North-West Territory and Manitoba: Contrib. Canadian Palæontology, 1889, vol. i, pl. xxvi, figs. 4, 4*a*.)

In 1907 Mr. George E. Dibley, F.G.S., who has for some years carefully collected the fossils of the Chalk formation of Kent, etc., was so fortunate as to obtain from the Turonian (Middle Chalk, in the zone of *Rhynchonella Cuvieri*) at Cuxton, near Rochester, three specimens of *Loriculæ* attached to the shell of an Ammonite, *Pachydiscus peramplus* (Mantell). These beautiful specimens are now preserved, like the type itself, in the Geological Department of the British Museum (Natural History).

Saving some small distinctions to be presently pointed out, and some additional details not preserved in Mr. Wetherell's original specimen, those now obtained agree generally with the type, but are more perfect and much larger in size. One point of very great interest lies in the fact that Mr. Wetherell's type-specimen, and those since discovered by Mr. Dibley, were all obtained from the same locality, and in each instance were found attached, parasitically, by the side

[1] Charles Darwin, Fossil Lepadidæ, 1851, pp. 81–6, Tab. v, figs. 1–4: Mon. Pal. Soc., 1851, vol. v.

[2] K. A. von Zittel, "*Loricula lævissima*, Zittel, Ob. Kreide, Dülmen, Westfalea": Sitz. der Math.-phys. Classe vom 8 Novr., 1884, pp. 586, 587, fig. 4. *Loricula lævissima*. "*Loricula Syriaca*, Dames, Cenomanian": op. cit., p. 589, fig. 5.

[3] W. Dames, "Ueber eine Art Cirripeden Gattung *Loricula* aus den Kreideablagerungen des Libanon (*L. Syriaca*)": Berlin Naturf. Freunde Sitzber., 1878, pp. 70–4.

[4] Dr. Anton Fritsch and Jos Kafka: "Die Crustaceen der Böhmischen Kreideformation Prag," 1887, pp. 1–3, Taf. i, 4to.

of the peduncle to the shells of Ammonites. This was also the case with all the examples of *Loricula* discovered and described by Dr. Fritsch from the Chalk of Bohemia (see *ante*).

Specimens of the still earlier *Pollicipes concinnus*, J. Morris (Annals N.H., 1845), from the Oxford Clay were also found in a group attached to the shell of an Ammonite, *Amm.* (*Cosmoceras*) *Elizabethæ*, from that formation, but in *P. concinnus* the peduncle was free and movable, not attached by one side to the Ammonite shell, only fixed by its base.

Fig. 1. The most perfect of the three specimens attached to the newly discovered Ammonite (*Pachydiscus peramplus*) from Cuxton, near Rochester, measures 45 mm. in length and 25 mm. in extreme breadth (the breadth being greatest across the peduncle at about the ninth row of scales, below the capitulum). Measured obliquely along the base of the capitulum where it unites with the peduncle, it is only 20 mm. in breadth, the height of the capitulum being 15 mm. and the length of the peduncle 30 mm.

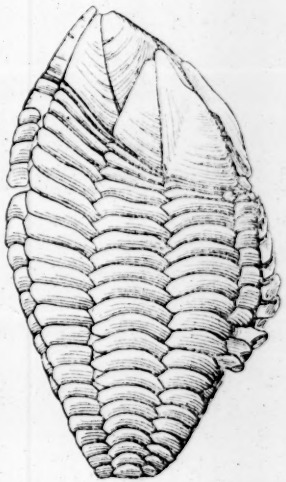


Fig. 1.—*Loricula Darwini*, H. Woodw., sp. nov., one of three specimens found attached to an Ammonite from the Middle Chalk, Cuxton, near Rochester, Kent, now in the British Museum, Geological Department. Drawn twice natural size. [Registered No. I. 9130.]

The *Capitulum*.—In an ordinary pedunculated Cirripede this would consist of 10 valves (4 being paired lateral valves and 2 marginal single ones), namely, 2 terga, 2 scuta, 2 carinal latera, 2 middle or upper latera, and, lastly, a carina and a rostrum.

In the original specimen of *Loricula* figured and described by Darwin, only 3 valves are preserved, namely, a scutum, a carinal latus, and a middle or upper latus; he assumes, however, that a tergum, a carina, and a rostrum must have been present when it was perfect, and that in order to complete the specimen a corresponding set of paired valves originally existed on the lower side of the capitulum.

In the newly obtained specimens the upper exposed surface (Fig. 1) of the capitulum shows the carina, see lettered Diagram-outline figure (Fig. 2, *c*); the second or carinal latus (*l*); the first, middle, or upper latus[1] (*l'*); the tergum (*t*); the right scutum (*sct*); and one sees the inner occludent margin of the left scutum (*sct'*) exposed beneath the right one.

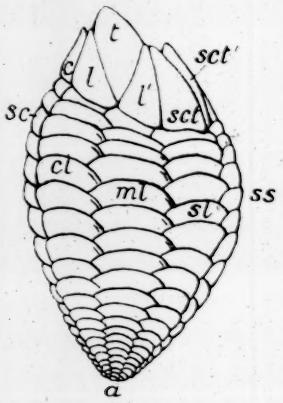


FIG. 2.—Diagram-outline of *Loricula pulchella*, G. B. Sowerby, var. *minor*. (After Fritsch.) From the Chalk of Bohemia.

Valves of *Capitulum*.—*c*, carina; *l*, carino-latus[2]; *t*, tergum; *l'*, upper latus or middle latus[2]; *sct*, scutum; *sct'*, edge of the pair-valve of scutum seen from the inside. (The small rostrum is not seen in any of the specimens, and was lost, or probably aborted.)

Peduncle.—*sc*, series of carinal scales; *cl*, carino-lateral series of scales; *ml*, medio-lateral series; *sl*, series of scutal scales; *ss*, sub-scutal (or sub-rostral) series of scales.

a, initial point of attachment of the young animal in the earliest stage of its becoming fixed and ceasing to be a free-swimming nauplius.

In all the specimens at present known and examined, however, the rostrum (usually a very small single valve lying at the base of the paired scuta) appears to have been absent,[3] but, arguing from the lines of scales seen in the peduncle, Darwin believes that a rostrum most probably existed. With this exception the capitulum may be said to be complete.

The small size of the capitulum, and its narrowness compared with the breadth of the peduncle, led Darwin "to believe that the greater

[1] In his monograph on the Fossil Lepadidæ (Pal. Soc., 1851) Darwin writes, p. 85: "In the imaginary restored figure [Tab. v, fig. 4, op. cit.] the tergum has its normal shape and manner of growth. The first latus now answers to the *upper* latus in *Scalpellum*, but it is interposed to a quite unprecedented extent between the scutum and tergum [see Fig. 2, *l'*]; the second latus [see Fig. 2, *l*] is on this view the carinal latus; and the rostral latus, always smaller than the carinal latus, and in *Scalpellum quadratum* and *S. Peronii* reduced to a very small size, is here quite aborted."

[2] *l'* is spoken of by Darwin also as the first latus; *l* is referred to by Darwin also as the second latus.

[3] It seems not improbable that in *Loricula* the rostrum may have been aborted in this curious parasitic form.

part of the animal's body was lodged in the peduncle, as in the recent genera *Lithotrya* and *Ibla*" (op. cit., p. 82).

We are, fortunately, able to record the complete series of the valves of the capitulum in *Loricula* as seen upon the exposed upper right side of the specimen recently acquired for the British Museum, with the exception of the rostrum, which may or may not have been present, but in any case it has not been preserved in any of the examples so far discovered.

Carina.—The carina is 5 mm. in height by 2 mm. in greatest breadth at its base, and tapers to a point at its summit; it is marked by fine transverse lines of growth. The 'carinal latus' (also called the 'second latus') is obliquely triangular; it is 5 mm. in height upon the carinal border, which is nearly straight, the apex only being slightly curved towards the tergum; the tergal border is slightly concave and is 10 mm. in length, the lower point being covered by the base of the middle or scutal latus (also called the 'first latus'); the base, which is somewhat curved, is 7 mm. broad.

The middle or first latus is 6 mm. in height on the tergal border and 8 mm. on the scutal margin (its apex is slightly abraded); its base 4 mm. broad. Resting between these is the tergum, which measures 7 mm. along its carinal-lateral border, 5 mm. upon its upper free occludent border, and 7 mm. on its latero-scutal border; both the upper points of the middle latus and scutum slightly overlap the tergum.

The scutum is the largest paired plate in the capitulum, being 8½ mm. in height along its lateral margin and 11 mm. along its occludent margin, the ascending wing being much prolonged upwards beyond the umbo, and very attenuated and narrow like the valve of a mollusc, such as *Neæra*, the base being 5 mm. broad; the lines of growth in the lower part of the valve are parallel to the tergo-lateral and basal margins; the umbo of the valve, which is largely developed and very prominent, is 5 mm. below the apex, in fact about midway on its occludent margin. Mr. Darwin writes (op. cit., p. 82): "In this important respect [the scutum of] *Loricula* resembles that of *Scalpellum magnum*, *S. tuberculatum*, and *S. cretæ*."

In evidence of the presence of both upper and under side of the paired plates to the capitulum in *Loricula*, the new specimen (Fig. 1) shows clearly, and Dr. Fritsch's specimen (Fig. 2) also, the inner margin of the second valve of the scutum (*scl'*) exposed beneath the occludent margin of the upper valve. It is along the occludent borders of the paired tergal and scutal plates that the cirri of the Cirripede are extruded in search of food, or again withdrawn within the capitulum when the animal is alarmed or at rest.

Peduncle.—This has a most singular, elegant, loricated structure; it is wider than the capitulum and twice as long. It is entirely covered, at least upon its exposed surface, by three nearly equal rows of smooth, calcareous scales, much elongated transversely, the ends of the scales in each row intersecting those in the adjacent rows[1] and

[1] The beautiful imbricated arrangement of the rows of transversely elongated calcareous plates, protecting the peduncle in *Loricula*, suggests at once comparison with the test of that anomalous Cretaceous Echinoderm *Echinothuria floris*,

corresponding in longitudinal order with the valves above each row in the capitulum, the left-hand long row (see Fig. 2, *cl*) being immediately below the carinal latus (*l*); the middle row (*ml*) below the median or upper latus (*l'*); the scutal row (*sl*) below the scutum (*sct*). Outside these are two very narrow rows of scales, that on the left-hand margin of the peduncle, named the carinal series (*sc*), being immediately below the carina (*c*), that on the right-hand (*ss*) being the sub-rostral (?) or sub-scutal row. On the same margin may be seen a portion of yet another series of narrow scales showing their *inner surfaces* (see Fig. 1, right-hand side of peduncle), which are no doubt the second row of sub-rostral or sub-scutal scales, forming the *attached* margin of the peduncle, but slightly displaced like the inner border of the left scutum (*sct'*) seen immediately above them.

Taking the rows in order, from left to right, in the peduncle, the first carinal row is only about 1½ mm. in breadth at the base of the carina, and the scales are almost rectangular oblong in shape and are not imbricated as in the three central series; they are 17 in number and diminish gradually downwards to about 25 mm. from the capitulum, when the series disappears, only the three central transversely elongated lines of scales being persistent to the extremity of the peduncle. Although visible in other specimens, as well as in Darwin's type-specimen, the small initial extremity of the peduncle in the large new specimen is imperfect (see Fig. 1). This tiny point may represent the loss of five or even six rows of very minute scales, so that in counting the number in these three central series five lost scales may very safely be added to each. The carino-lateral row is 5 mm. broad just beneath the latus; there are 23 scales in the longitudinal series (+ 5 missing = 28), which is one more than in the median row. These scales are not imbricated with the carinal row, being only united by a straight, simple line of suture, but on the inner border the end of each scale is pointed where it interlocks with two rows of the median series, so that the scales in each series alternate with the row adjoining it. The scales are slightly arched along their upper margins, and after the ninth scale, counting from the capitulum, they diminish rapidly in breadth to the apex. The median lateral scales are the most symmetrical series; they are slightly wider (near the middle of the peduncle) than those on either side, and each scale is pointed at both ends, their upper margins being flatly arched near the capitulum, and more strongly arched in the lower part of the peduncle. They have one less scale (22 rows) than in the preceding series, and they diminish less rapidly in breadth downwards than the lateral series of scales.

The scutal series of scales are 4 to 5 mm. broad at their upper and

S. P. Woodward, described and figured in the *Geologist* for 1863, vol. vi, pp. 327–30, pl. xviii, in which the test of the Echinoid is rendered flexible by ten segments, or a double series of imbricating calcareous plates. See also Wyville Thomson's account of the living genus *Calveria* (*Asthenosoma*) *hystrix*, in "Depths of the Sea," 1873, pp. 155–9, and Phil. Trans. Roy. Soc., 1874, vol. clxiv, pp. 730–7; and Professor J. W. Gregory on Echinothuridæ, etc., Quart. Journ. Geol. Soc., 1897, vol. liii, pp. 112–22.

widest part; there are 21 rows, not counting the lost small extremity; the scales in each row are pointed at their inner end where they unite with the alternate rows of the median lateral series, but they unite by a nearly straight suture with the sub-scutal or sub-rostral series. This outer (rostral?) row (like the carinal row on the opposite side of the peduncle) is only 1½ mm. broad; the scales are almost rectangular in form and are evidently incomplete at their lower end, only 8 being preserved. Beyond this row is seen yet another series, 10 in number, evidently a second rostral series, belonging to the margin of the lower side of the peduncle, attached to the shell of the Ammonite, as they show the inner surface of the scales slightly displaced, having only a straight suture-line to unite them with the overlying narrow series.

Writing of the peduncle (p. 82, op. cit.) Darwin says: "The base is sharply pointed, down to which the full complement of scales extends. In each row there are about 21 scales, their number obviously depending on the age and size of the individual" (p. 83).

We have already pointed out the difference in the number of scales in the three principal series, viz., 23 rows in the carino-lateral, 22 in the median, and 21 rows in the scutal series, causing the very oblique arrangement of the capitulum, which slopes downwards from the carina towards the scutum. Darwin also refers to this: "There is one more scale under the second latus than under the first [or middle] latus, and one more under this than under the scutum; hence the summit of the peduncle is obliquely truncated, being lowest at the rostral end. In this respect there is some resemblance to the genus *Lithotrya*."

Growth.—Under the subject of growth Darwin says (p. 84): "New scales for the peduncle are formed round its upper edge at the bases of the valves of the capitulum, the chief growth of which is downwards: hence we here have, as in other pedunculated Cirripedia, a principal line of growth round the summit of the peduncle. It can be seen that a new scale is first formed under the second latus, at the carinal end of the peduncle, and this agrees with the fact that there is one more scale in this row than in that next to it, and one more in the latter than in the row under the scutum. I may mention, as in conformity with this fact, that in the development of the young of *Scalpellum vulgare* from the larval condition the calcareous scales on the peduncle first appear under the carina."

In Darwin's description of *Loricula pulchella* (op. cit., p. 81) he describes the peduncle as having "*ten rows* of smooth calcareous scales, five rows upon the *upper* and five rows on the *under* surface of the peduncle, of which the six lateral rows are much elongated transversely, and the four end rows narrow; and that along the rostral and carinal margins of the peduncle there is a straight medial suture, with the scales not intersecting each other."

Having carefully removed the Chalk from beneath one of Mr. Dibley's specimens (now in the British Museum, No. I. 9130), I find that the three principal rows (Fig. 1, *cl*, *ml*, and *sl*) of much elongated calcareous scales are absent, and I therefore venture to suggest that they were *not developed upon the underside* of the peduncle, which was attached to the shell of the Ammonite along the margins (Fig. 2, *sc* and *ss*),

the mode of growth of *Loricula* being *always prone*, from the time it first abandoned its free-swimming larval existence and became fixed at the initial point (*a*), only the capitulum retaining its valves complete on both surfaces, so as to enable it to open and close its body-cavity and allow the cirri to be freely protruded and retracted at pleasure. Darwin has himself stated that "in *Loricula* the attachment was probably by one lateral face of the lower part of the peduncle, for it is by no means unusual for the cement-stuff (even when proceeding only from the two original central orifices, where the prehensile antennæ of the larvæ may still be found) to encroach largely on the peduncle, and thus fix it down. The calcareous scales of *Pollicipes* and the horny spines of *Ibla* may often be found thus embedded and firmly fixed to the supporting rock; it is, moreover, possible that in *Loricula* the cement was poured out of orifices specially situated on one side of the peduncle, as takes place along the rostral margin in *Scalpellum vulgare* and high up on both sides of the peduncle in *Lepas fascicularis*" (Darwin, op. cit., p. 84).

Mr. Darwin states that Mr. Wetherell's original type-specimen which he so carefully described was found "embedded outside the cast of an Ammonite" (op. cit., p. 82), from which it appears he did not quite realize that it was adhering to the shell and parasitic upon the Ammonite, as *Coronula balænaris* attaches itself to the skin of the whale, and *Chelonobia testudinaria* and *C. caretta* affix themselves to the carapace of the turtle to-day.

The abundant evidence now obtained from the Chalk of Bohemia and the Chalk of Kent as to the habit of *Loricula* to live attached to the shells of Ammonites is conclusive that it was always firmly fixed by one side of its peduncle, and that in all probability the calcareous scales were only developed upon the upper exposed surface.

In connection with this remarkable loricated form of Cirripede *Loricula* it may not be uninteresting to quote the observations of Monsieur A. Gruvel, who has devoted so many years to this group:—[1]

"It is impossible for us to arrive at an exact idea of the form under which the first ancestor of the Cirripedia showed itself after the initial *Cypris*-state. In the present condition of our palæontological knowledge of these animals, the first traces which remain to us are met with in the Silurian and Devonian strata of Europe and North America by those calcareous scales, very similar in appearance, which were considered by Professor de Koninck as the plates of Chitons (*Chiton Wrightianus*), by H. Woodward as peduncular scales, and by Barrande as part of the capitulum of a Cirripede.

"Our opinion is that they are the remains of the *complete imbricated covering* of a primitive Cirripede, first correctly designated by H. Woodward under the name of *Turrilepas*. The real animal may be said to have been enclosed in this species of scaly cylinder, which afforded only a poor protection to its appendages and soft parts. To furnish a more efficient shelter, the plates of the upper row were

[1] "Monographie des Cirrhipèdes ou Thécostracés," par A. Gruvel, Université de Bordeaux. Roy. 8vo, pp. x + 472 = 482, avec 427 figures in text. Paris: Masson & Cie., 1905.

much more specially developed than the others, and the hard external covering was more completely divided into two series; the upper series being more developed to form the plates of the *capitulum*, whilst the remaining rows, nearly all alike in form, constituted the scales of the *peduncle*. It is here that we have observed a modification in a form belonging to the Cenomanian (*Loricula Syriaca*, Dames) and in another form from the Upper Chalk (*Loricula pulchella*, Sow.). The evolution beginning in this way becomes more and more apparent, in such a manner as to constitute finally the forms with which we are familiar in both a fossil and recent state, as *Pollicipes* for example, in which two very distinct general regions exist, one above forming the capitularian plates, which are well developed and most thoroughly protect the soft parts of the animal, and another lower region, serving solely as a support and covered by the peduncular scales, nearly all alike and much smaller in size than those of the capitulum.

"The above deductions are supported clearly, not only by palæontological proofs which we shall specify, but also facts of embryology and anatomical details.

"Therefore, if, for example, one studies the post-larval development of *Pollicipes polymerus*, Sow., one sees that in very young specimens it is impossible to define the capitulary region because the lower plates of the capitulum nearly resemble the upper scales of the peduncle.

"Again, Koehler was the first to point out an organ in the centre of the scales of *Pollicipes*, which we have described after him as being an organ of sensation. One finds this again, modified it is true, quite in the inferior plates. It only disappears in those in which the scales have arrived at a much higher stage of development.

"We see, on studying each of the sections of this sub-class, how the different forms are derived from the primitive type and how they are connected again one with another." (Gruvel, Introduction, pp. 5, 6.)

This large *Loricula*, both on account of its much greater size and more remarkable capitulum, merits recognition as a new species, rather than to be placed with *Loricula pulchella* or only treated as a variety. If such distinctive points as the form of the scutum and the latera deserve specific recognition,[1] I desire to name it after the illustrious author of the monograph on the Cirripedia [published by the Ray Society, 1854], and of the fossil Lepadidæ and Balanidæ [by the Palæontographical Society, 1851 and 1854], *Loricula Darwini*,—whose great work on "The Origin of Species by Natural Selection" has just been celebrated by the Linnean Society of London.

I am much indebted to my friend and former colleague for so many years, the present Keeper of the Department of Geology, Dr. Arthur Smith Woodward, F.R.S., for giving me the pleasure of describing this fine, newly discovered *Loricula* from the English Chalk, which has now been added to the National Collection.

[1] A comparison of *Loricula Darwini* (Fig. 1, *supra*, p. 493) with that of *L. pulchella*, var. *minor* (Fig. 2, p. 494) will emphasize the specific differences between the former and the latter. Fig. 2 agrees closely with Darwin's original figure of *L. pulchella* (Mon. Pal. Soc., 1851, T. 5), especially in the outline of the valves of the capitulum, and both differ markedly from the capitulum of *L. Darwini*, as drawn in our Fig. 1.

IV.—Notes on the Petrography of Egypt.[1]

By W. F. Hume, D.Sc., A.R.S.M., F.G.S., Superintendent, Geological Survey of Egypt.

(WITH A PAGE MAP.)

PRIOR to the foundation of the Geological Survey of Egypt in 1896, the general relations of the sedimentary strata had already been established on a firm basis by the labours of numerous observers, but the characters and affinities of the igneous and metamorphic rocks had been but little investigated. Such studies as had been made were more or less isolated in character, those that had been carried out including a description of rock-specimens from the First and Second Cataracts by Newbold,[2] Delesse,[3] Dawson,[4] Bonney,[5] and Miss Raisin,[6] of the Abu Zabel basalts by Arzruni, of some Eastern Desert rocks by Liebisch (Zeitschr. d. Deutsch. Geol. Gesellschaft, 1877, xxix, p. 712), and, in addition, the principal ornamental rock of Egypt, the Imperial Porphyry, had received special attention (see references in Barron & Hume, "Eastern Desert of Egypt," p. 236, etc.),[7] but a general picture of the petrographical history of Egypt as a whole has not yet been delineated. Pending a more detailed description of the Egyptian igneous and metamorphic rocks, the following epitome of the results already obtained may be of interest, the region under consideration embracing Egypt and the Sudan, the peninsula of Sinai, and the countries immediately adjacent.

The subject may be most conveniently considered under the following six divisions:—

I.—Gneisses: (*a*) Cataract gneisses, (*b*) Arabian Desert gneisses.
II.—(*c*) Pre-Carboniferous plutonic rocks, (*d*) red granite, (*e*) igneous dykes.
III.—Pre-Carboniferous volcanic and sedimentary series.
IV.—Ancient metamorphics of schistose character.
V.—Carboniferous and post-Carboniferous volcanic activity.
VI.—Early Tertiary volcanic occurrences.

I.—Gneisses.

(*a*) There is little doubt that the ancient continental core of this vast area is represented by the *Cataract* and *Sudan* gneisses and schists, which often display banding of marked character, both the more closely foliated schists and highly crystalline gneisses being

[1] A brief abstract of this paper appeared in the Geological Magazine for October, p. 465. Read at British Association, September 4, 1908. Given by permission of Director-General, Survey Department.

[2] "On the Geology of Egypt": Q.J.G.S., 1848, vol. iv, pp. 324–49.

[3] "On the Rose-Coloured Syenite of Egypt": Q.J.G.S., 1851, vol. vii, pp. 9–13.

[4] "Geology of Egypt": Geol. Mag., 1884, pp. 289–92, 385–92, 439–42.

[5] "Note on the Microscopic Structure of some Rocks from the neighbourhood of Aswan": Geol. Mag., 1886, pp. 103–7.

[6] Geol. Mag., 1893, pp. 436–40, and Q.J.G.S., 1897, vol. liii, pp. 364–73 (on rocks collected by Captain Lyons).

[7] There are also some notes on the rocks from the Sinai Peninsula by Professor Bonney in Palmer's "Desert of the Exodus" (1871, p. 556), and by Mr. Rudler in Appendix B of Professor Hull's Memoir on the Geology, etc., of Arabia Petræa.

represented. In general the latter consist of highly acid and hornblendic or mica-bearing varieties, as granitoid gneiss forming the main rock in Uganda and the Southern Sudan. They extend from Kordofan to the base of the Abyssinian hills (where the volcanic series overlies this ancient formation), and once more reappear as prominent members in the various cataract regions. The banded gneisses have also been proved to be the fundamental member north of the Shabluka rapids (Sixth Cataract), between Abu Hamed and Shirri Island in the Fourth Cataract, forming the base-rock of the Third Cataract region, of Semna, and of Ambugol, between Dongola and Wady Halfa, and are again present in the outskirts of Aswan. Nor are they absent in the great deserts east and west of the Nile, for the writer has met with them near the Arbain Road far south of Kharga Oasis, and west of the Nile between Ibrim and Dungul, while in the Eastern Desert they form the bold peaks of Meeteq, of Sebahi, and the Abu Tiur, familiar to all travellers down the Red Sea, and are of the widest extension both near the emerald mines of Sikait and in the desert south-east of Aswan. This ancient series still requires most careful and exhaustive study, and may in part at least represent an intrusive magma anterior to the great post-Archæan sedimentary series, which will be described later. Dawson has remarked on their great resemblance to the Laurentian series of North America, and the Cataract gneisses also appear to agree closely with the Bengal gneisses of India (see Vredenburg, Summary Geol. India, p. 5).

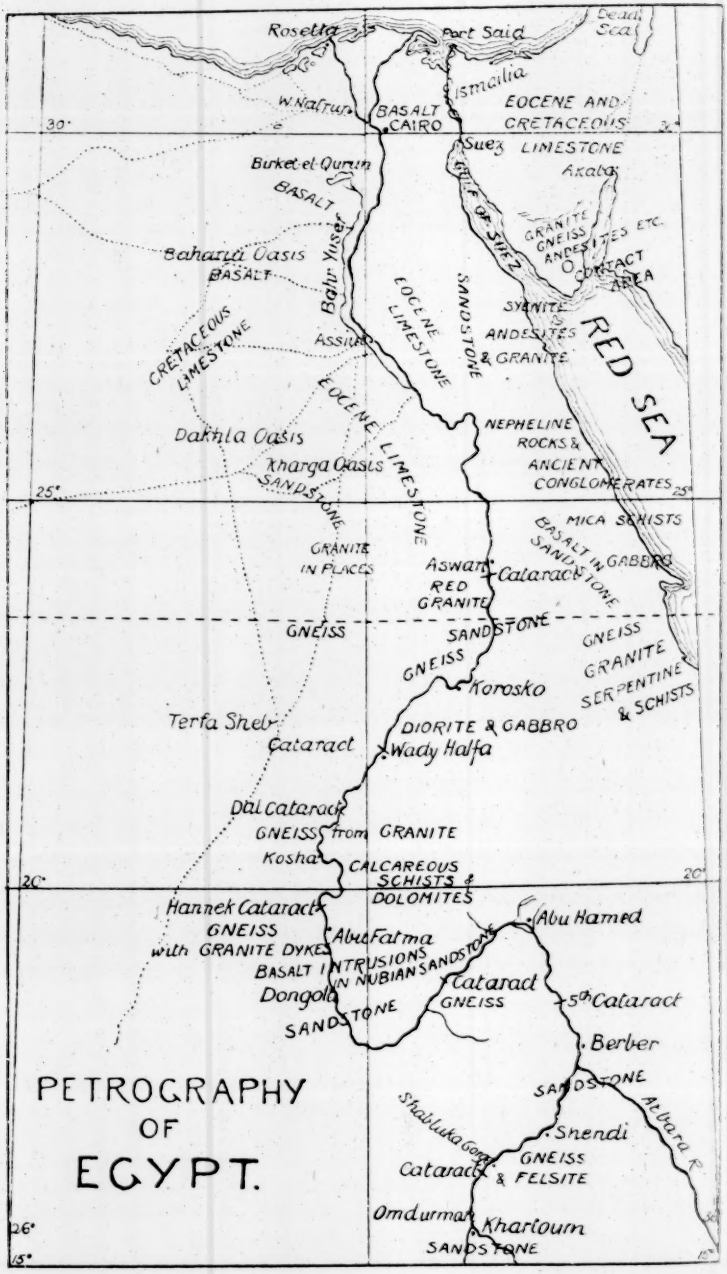
Although the main banding or foliation of these rocks appears to be an original structure, or, if the result of earth-movements, of very ancient date, a pseudo-foliation has in some cases been produced, due to the intrusion of thin granitic veins between the foliated gneiss, giving rise to a very coarsely banded variety, such as is present at Nab Island, in the Third Cataract area, north of Dongola.

The gneiss of the Dal Cataract region, south of Wady Halfa, can also be distinctly traced back to a granite with large porphyritic felspar crystals, but it is open to question whether this rock is of as great an age as the more highly foliated members, rich in mica or hornblende, which form the principal constituent of this division.

(*b*) A second type of gneiss, that of the Arabian Desert, has a very wide extension in the Eastern Desert and Sinai, but has no marked foliation except in isolated instances. It agrees with the Bundelkhand gneiss of India in having the general characters of a fairly coarse pink granite, though many varieties have been observed. The evidence available indicates that this series represents a granitic magma which has played a most important part in the structure of the Eastern Desert and Sinai.

These great acid intrusions appear to have been of two dates, one preceding the deposition of the pre-Carboniferous sedimentaries, as these contain fragments of granitic rocks (both hornblendic and more acid types) among the boulders and pebbles of their conglomerates. A younger granite invasion has subsequently produced marked contact changes, especially in Eastern Sinai.

It is difficult at present to indicate definitely the origin of the banded gneisses, though the writer after examination of these rocks


Rosetta
Port Said
Dead Sea
Ismailia
W. Natrun
BASALT
CAIRO
EOCENE AND CRETACEOUS
30°
Suez
LIMESTONE
Akaba
Burket el Qurun
BASALT
GULF OF SUEZ
GRANITE GNEISS ANDESITES ETC.
CONTACT AREA
Bahariya Oasis
BASALT
Bahr Yusef
SYENITE ANDESITES & GRANITE
RED SEA
EOCENE LIMESTONE
SANDSTONE
CRETACEOUS LIMESTONE
ASSIUT
EOCENE LIMESTONE
Dakhla Oasis
Kharga Oasis
SANDSTONE
NEPHELINE ROCKS & ANCIENT CONGLOMERATES
25°
MICA SCHISTS
BASALT IN GABBRO
SANDSTONE
GRANITE IN PLACES
Aswan
Cataract
RED GRANITE
GNEISS
SANDSTONE
GNEISS
GNEISS
GRANITE
SERPENTINE & SCHISTS
Korosko
Terfa Shelf
Cataract
DIORITE & GABBRO
Wady Halfa
Dal Cataract
GNEISS from GRANITE
Kosha
CALCAREOUS SCHISTS & DOLOMITES
20°
Hannek Cataract
GNEISS with GRANITE DYKES
Abu Fatma
Abu Hamed
BASALT INTRUSIONS IN NUBIAN SANDSTONE
Cataract
GNEISS
5th Cataract
Dongola
SANDSTONE
Berber
SANDSTONE
Atbara R.
Shabluka Gorge
Shendi
Cataract
GNEISS & FELSITE
Omdurman
Khartoum
SANDSTONE
26°
15°
PETROGRAPHY OF EGYPT.

over wide areas leans to the view that these represent the earliest igneous intrusions observed in Egypt, and that the magma was more readily plastic than in the later intrusions.

No such difficulty exists with regard to the Arabian Desert gneiss, which in a large number of cases reveals its granitic or igneous origin by the effects produced where it is in contact with the ancient sedimentaries subsequently described, and is thus directly connected with

II.—The Pre-Carboniferous Plutonic Rocks.

(*c*) The rocks of this series vary from the most highly acid granites to ultra-basic varieties. Of these undoubtedly the most interesting is the *Red Granite* of Aswan, which has recently been described by Ball ("Aswan Cataract," p. 70) in some detail. This rock is characterized by the large idiomorphic crystals of orthoclase, associated with quartz, biotite, and hornblende. The latter is very variable in quantity.

Ball has further shown that the granite has undergone intense crushing, the orthoclase having been completely changed to *microcline*,[1] while round the large crystals is a 'mortar' of small granules resulting from the attrition consequent on the sliding produced by the act of crushing.

During the course of the Survey much interesting material has been collected bearing on the results of contact-metamorphism near the junction of the plutonic rocks and the schistose (ancient sedimentary) rocks into which they have been intruded. The plutonic rocks in numerous instances have been found to undergo a change from acid to more basic varieties. In Sinai, near Dahab, the gneissic fringes are well marked, hornblende or mica increase in quantity near the junction, and *sphene* may become an important constituent.

Syenites in general are rare, though well developed at Aswan and Jebel Zeit, but *diorites* are of the widest extension throughout the Arabian Desert. The dark rocks constituting the principal member of the Second Cataract at Wady Halfa is also of this nature, the hornblende being present in large quantity. *Quartz diorites* are especially present in the neighbourhood of the Imperial Porphyry region of Dokhan.

In some areas *basic rocks* attain unusual development, especially in the neighbourhood of the Qena-Qosseir Road, about lat. 26° N., between the Nile and the Red Sea. These usually are in the form of coarse *gabbros*, which are composed of plagioclase and augite, but the latter readily changes to hornblende. Locally the rock may be almost purely composed of diallage, and under such conditions is sometimes highly magnetic, while at El Ranga, near the old Berenice, hæmatite has been produced by concentration from a gabbro rich in a ferruginous constituent. A very hard gabbro is also present in the

[1] The formation of microcline appears to be associated with the crushing in this case, but that it always originates in this way is not implied in the above remarks. Professor Bonney (in a letter) mentions the 'Laurentian gneisses' as a case where no such evidence is forthcoming.

Second Cataract, forming the sides of the Bab-el-Kebir rapid, whose presence is due to the wearing away of a porphyrite dyke intrusive in the massive basic rock.

Norites, etc., have been observed locally in the Eastern Desert, but their general relations are still obscure, and massive beds of dolerite form an important constituent between Qena and Qosseir.

The rarity of felspathoid rocks in Egypt renders occurrences of this nature of special interest. In 1896 Mr. Barron brought back a rock from the Wadi Zeidun which in section showed hexagonal and rectangular sections strongly recalling *nepheline* in appearance, though internal strains had rendered the hexagonal sections nonisotropic. The position of the specimen was not precisely fixed, but last year the writer brought back a variety from Jebel Hadarba which attracted M. Couyat's attention. Having made a section from the specimen, he has privately informed the writer that we are here dealing with a representative of the *nepheline-syenites*, so that the central region of the Arabian Desert between lats. 25° and 26° N. will probably yield felspathoid-bearing varieties over an extended area.

II (*d*).—A much younger group of acid intrusions is of the greatest geographical importance, it being the most notable mountain-former in Eastern Egypt and Sinai. This is the *red granite* (mainly composed of quartz and felspar, with occasional nests and films of muscovite mica), which is widely distributed in its range. Some of the finest mountain masses are composed of this rock (Um Shomer and Ed Deir in Sinai, El Shaib and the Gattar range, etc., in the Eastern Desert), while in the Cataract regions it gives rise to the rugged hills of Akasha, south of Semna, and the boulder-strewn region of Shirri, in the Fourth Cataract. Possibly in part contemporaneous with it are—

II (*e*).—The dykes of varied composition (granites, felsites, dolerites, etc.) which seam the greater part of the Egyptian igneous and metamorphic rocks, and themselves have complicated inter-relationships, as mentioned in the Egyptian Geological Survey Memoirs.

1. *Acid types.*—Of these the most conspicuous and common are the close and often coarse intergrowth of quartz and orthoclase felspar, frequently known under the name of *pegmatite granite*. It is probable that every region in Egypt provides examples of this type. Ball ("Aswan Cataract," p. 84) states that it is the most frequent rock at the Cataract, though actual graphic structure is uncommon. It is also well developed in the Eastern Desert north of Qosseir and near the Sikait emerald mines, while a beautiful graphic form was obtained by Stewart at Gebel Ribdab in the south, near the Sudan frontier.

2. In the second rank are a group of *microgranites* (notably in West Sinai) occasionally containing porphyritic crystals of orthoclase and plagioclase, while locally a beautiful granophyric structure is developed.

3. *The quartz porphyries*, or felsites with microcrystalline base, are not so prominent as those of microgranitic type, but typical examples were obtained by Barron at Ain-el-Akhdar, in West Sinai, and from Jebel Zeit, in the Eastern Desert.

4. *Felsitic types*, showing well-marked *spherulitic* structures, have

also been obtained from Wadi Barud (Eastern Desert of Egypt north of Qosseir) and at several localities in East Sinai.

5. *Intermediate types.*—Ball has recorded the presence of a boss of highly-altered *syenitic porphyry* between Aswan and Shellal, characterized by the presence of abundant lath-shaped orthoclase felspars.[1] This type is, however, rare in the Eastern Desert and Sinai, rocks which from hand-specimens had been regarded as such being mainly very fine-grained granites with quartz in fairly large proportions.

Well-marked dykes of *diorite* have been observed in West Sinai, and further study will probably show these to be of considerable importance elsewhere.

Very noticeable in every part of the igneous region from Sinai to the Fourth Cataract are a series of chocolate-brown or light-yellow rocks (often with satiny lustre) which are referable to the *porphyrites*. Ball has described some interesting examples from near Aswan, including a variety rich in enstatite from near Sehel Island, and another from East Sinai, near Dahab, was closely related to a Bostonite, but was more coarsely crystalline (see Hume, "Eastern Sinai," p. 163).

6. *Basic types.*—These are extremely numerous, and often as much as thirty metres wide, showing cannon-ball weathering. The dense black types are usually dolerites, the easily decomposed varieties diabases.

All these intrusive and crystalline rocks are pre-Carboniferous in age, and were formed *anterior to the deposition of the Nubian Sandstone*.

The researches of the Survey have brought into view the importance of a further group of rocks, which, though geographically closely connected with the intrusive granites and gneisses, are of totally different origin and character.

III.—The Pre-Carboniferous Volcanic and Sedimentary Series.

At a very early stage in the work of the Survey it was found that volcanic rocks closely connected with sedimentary formations played a most important part in the history of the Eastern Desert and Sinai. Rhyolites of typical character were obtained from near Qosseir, in the Ferani Hills of East Sinai, and were also well developed in the Shabluka (Sixth Cataract region) north of Khartoum. To this series also belongs the well-known manganese-bearing andesites and porphyrites of Jebel Dokhan (the Imperial Porphyry), the andesites of Jebel Katherina and many other summits in Sinai and the South-Eastern Desert, and the dolerites or basalts developed on a large scale between Qena and Qosseir. Serpentines also are of the widest distribution, and near Sikait are exceptionally developed, while Dr. Ball has now reported them to attain an unusual importance in the region he has recently studied in the South-Eastern Desert near the frontier-line of the Sudan and Egypt, he having proved that the mountains of Abu Dahar, Gerf, Korabkansi, etc., are entirely composed of this type of rock.

[1] The identification is based on the predominance of simple twinning.

Closely associated with these evidences of intense volcanic activity are the metamorphosed sedimentary strata which, once grits and conglomerates, are now changed to slates and crushed conglomeratic beds. Isolated occurrences of these rocks, and especially the conglomerates, had been recorded, for instance, by Professor Hull in Sinai, and by Captain Lyons on the road between Korosko and Abu Hamed, while the Breccia Verde Antico of Hammamat was well known to all archæological students. These rocks are now known to be developed throughout the desert from East Sinai to the confines of the Sudan. Occurring to the north in isolated areas, they play a most important part in the Eastern Desert of Egypt in lat. 26° N.

This ancient series often presents the most interesting metamorphism where it comes into contact with or overlies the granitic rock. M. Couyat, who had the advantage of studying under M. Lacroix, has pointed out to me that the remarkable basic-looking fringes surrounding some of the granitic masses agree in all particulars with the 'roches cornéennes,' and thus represent contact alterations of the sedimentary rocks by the granite with which they are in immediate contact. In East Sinai, in a district north-west of Nebk, a palm-grove on the Gulf of Aqaba, the contact-phenomena are very striking. Veins from the granitic intrusive mass have in some parts penetrated between the laminæ of the sedimentary slates, giving rise to a rock having the appearance of a mica-gneiss, the well-known *lit par lit* structure. Elsewhere the sediments, probably in part volcanic in origin, have been altered to hornblende-schists[1] near the point of contact, and gradual stages can be traced from this marked alteration at the boundary to garnetiferous mica-schists and spotted slates in the central portions of the areas. The sedimentary strata show every variation from fine-grained slates to conglomerates made up of the most varied materials, among which granites and porphyries are conspicuous. In places they contain quartz-pebbles which have been fractured and recemented, and their detailed study will undoubtedly throw much light on their origin and derivation. The absence of any fossil evidence renders the determination of their age a matter of comparison only. It may be stated broadly that they are pre-Carboniferous and post-Archæan, and appear to have close lithological resemblances to the Pebidian beds of Wales.

IV.—Ancient Metamorphics of Schistose Character.

In addition to the coarse gneisses of the Cataracts and the metamorphosed ancient sedimentaries, there is a series of rocks which may in part be connected with the first-named, and in part represent the remnants of an older period of sedimentation and vulcanicity. This includes the highly-foliated, dark, emerald-bearing mica-schists of Sikait, with which are associated beds rich in talc and tourmaline. These rocks immediately overlie a highly banded gneiss, and in Sikait

[1] The writer has stated the opinion to which he was led by the field relations in dogmatic form, but fully recognizes that the conditions are exceptional. The ordinary explanations of the origin of these schists failed to satisfy the conditions observed.

separate this coarse metamorphic rock from a highly complicated grouping of schists and serpentines.

In the Cataract districts are schists of very complex structure and origin, judging from the preliminary studies already made. One of these from the neighbourhood of Amara (between Wady Halfa and Dongola), which was examined by the writer with the kind co-operation of Dr. J. W. Evans, proved to be a labradorite-wollastonite-zoisite rock. In close connection with this series were some calcareous-looking bands which did not respond to the action of dilute acid, but in microscopic section proved to be *dolomites* whose origin must for the time being remain doubtful, though it is probable that they are derived from the alteration of early Palæozoic or even pre-Cambrian limestones. Another line of change is indicated by the presence of true *marble* bands intercalated between the schistose and gneissose members.

Taking the distribution of the metamorphic and sedimentary rocks as a whole, the writer is inclined to the view that sedimentation and intrusion have succeeded each other at least twice in the pre-Carboniferous periods in Egypt, foliation being most marked in the archaic epochs represented by the Cataract gneisses. Up to the present time no fossil records have been obtained which would supply a date for the ancient sedimentary strata, though there is always a possibility that such materials may yet be forthcoming. Such evidence as is available shows conclusively that all these ancient strata are pre-Carboniferous, the first fossiliferous sandstones containing a late Carboniferous fauna lying unconformably upon them.

V.—Carboniferous and Post-Carboniferous Volcanic Activity.

There have been at least two periods of volcanic activity in Egypt since the Nubian Sandstone was first laid down. The earliest occurrences of this nature at present known are the basic eruptions recorded in Western Sinai by Mr. Barron, the most interesting rock-type being a uralite-diabase from the summit of Sawasia.

During the Survey operations of 1905 a series of volcanic rocks of varied composition (rhyolites, andesites, and basalts) were noted in lat. 25° N., about midway between the Nile and the Red Sea, and immediately underlying the Nubian Sandstone, while in the same neighbourhood were conspicuous summits (Jebel Sufra,[1] the Nahuds, etc.) which are either volcanic rocks or lava-flows still showing a distinct columnar structure. Mr. Ferrar studied the Nahud necks and found them to be trachytic in nature, while Charteris Stewart brought andesitic rocks from the summit of Sufra. At El Ranga, on the Red Sea, in about lat. 24° 50′, an andesite (once a lava-flow) is now intercalated between the beds of sandstone, thus fixing the age of these lavas as not being greater than that of the Nubian Sandstone itself.

In the Northern Sudan south of Wady Halfa is a series of basic rocks of basaltic character, which is evidently younger than the associated Nubian Sandstone, the latter having undergone marked change to

[1] Mr. Wells had previously brought the writer an instructive photograph of Jebel Sufra, and had remarked on the marked evidence of volcanic action at that locality.

columnar structure where in direct contact with the intrusive material. One of the most conspicuous occurrences is on a low hill at the east end of the Kaibar Cataract, and other striking examples are seen at Delgo, at Jebel Alarambia, near Kerma, at Jebel Alibersi, and at El Lagia, in the El Kab Oasis near Dongola. The contact alterations are distinctly marked not only by the formation of the columnar sandstones, but by highly crystallized quartzites. As the intrusive rock has the altered sandstone both above and below it in the Alarambia district, its age is probably of the same period as those previously mentioned.

VI.—Early Tertiary Volcanic Occurrences.

The basaltic rocks in the north of Egypt and Sinai appear to belong to a later period of eruption, being closely connected with the Oligocene Continental Period. In the Fayum and near Cairo they overlie limestones of Upper Eocene age, and are overlaid by the Miocene and Oligocene strata where the latter are present, in the former case giving rise to the well-known precipitous shelf above the Birket-el-Qurun Lake, while at Abu Zabel, north of Cairo, they are of considerable economic importance. The rock is classed as a basalt on account of its ophitic structure, but in its typical development olivine is markedly absent. A rock of the same type has also a wide extension both to west and east, having been recorded from Baharia Oasis, from Gara Soda and Gebel Gebail in the Nile Valley, and from Western Sinai. These resemble the Cairo basalts in all essential particulars.

In addition to these occurrences in the north of Egypt, some interesting intrusions of andesitic and trachytic masses into Eocene limestones have been recorded by various members of the Survey. This is notably the case in an area east of Assiut examined by Beadnell, and from Jebel Abuhad, near Qena, examined by Barron and the writer.

Summary.

1. The ancient core of the North-East African Continent consists of the Cataract and Sudan banded gneisses, which may represent a very ancient igneous magma. They are usually much veined by granitic dykes.

2. In certain places in the Arabian Desert, Cataracts, etc., these underlie highly metamorphosed schists (the mica-schists of Sikait, the calcareous schists of Um Garaiart and Haimar and of the Amara Cataracts, also the dolomites of the latter region) which are sharply separated from the banded gneisses and are possibly the oldest sedimentary representatives in Egypt.

3. The greater part of the mountainous regions of the Eastern Desert and Sinai are occupied by two types of rocks, a schistose constituent overlying or being surrounded by the acid member. (*a*) The first-named, the *Dokhan volcanic rocks* and *schists*, are partly volcanic in origin and partly sedimentary, the former being represented by lavas of various types, while the latter are clearly altered sedimentary strata (grits, conglomerates, etc.). No fossils have yet

been found, but they have their nearest lithological analogues in the latest pre-Cambrian and Cambrian series. Here are included some of the most interesting rocks of Egypt, such as the Imperial Porphyry and the Breccia Verde Antico. (*b*) The igneous member intruded into these ancient sediments, etc., includes a great diversity of igneous rocks, varying from highly basic to acid types.

Contact-phenomena of complex nature occur at the junctions of (*a*) and (*b*).

4. *Red granite* and dyke rocks, whose parallelism and extent of distribution present one of the most conspicuous features of the Eastern Desert of Egypt, mark the final eruptive action before Carboniferous times.

5. Three periods of volcanic activity have been subsequently noted—

(*a*) In Western Sinai in late Carboniferous times.

(*b*) An undated series of eruptions interbedded with the base of the Nubian Sandstone or intrusive into it with marked contact alterations.

(*c*) The basic intrusions near Cairo and the Fayum, etc., which are intimately associated with the Oligocene Continental Period in Egypt.

V.—On the Phyllis Collection of Inferior-Oolite Fossils from Doulting.

By L. Richardson, F.R.S.E.

THE Inferior Oolite and contiguous deposits of the neighbourhood of Doulting have been described in detail in my paper on "The Inferior Oolite and Contiguous Deposits of the Bath-Doulting District";[1] but since that paper appeared, through the courtesy of the Urban District Council, I have had the loan of the John-Phyllis Collection of Inferior-Oolite fossils that are housed in the Shepton-Mallet Museum.

This collection is probably only a portion of that made by Phyllis, and although deficient in a number of specimens that are still to be found in the neighbourhood, is a useful one, and contains a considerable number that were not included in my lists.

John Phyllis, of course, knew the localities whence his specimens came, but—as is, unfortunately, so often the case—does not appear to have been sufficiently particular about labelling them with their localities. In a number of cases "near" Doulting must be understood. At the time the collection was submitted for revision the legends, in the majority of cases, read simply "L[ower] O[olite], Doulting." In a number of cases also it was certain that even this information was erroneous. For example, a *Schlotheimia* of the *S.-angulata*-Group, from the Lower Lias, was similarly stratigraphically allocated and localized. However, a knowledge of the

[1] Quart. Journ. Geol. Soc., 1907, vol. lxiii, pp. 383–444.

neighbourhood and matrices has enabled me to indicate with little possibility of error both approximate horizons and localities; but in studying the following lists it must be remembered that they are only approximations. Where the evidence was insufficient for more precise stratigraphical allocation the subdivision-columns are left blank and the more-embracing name of "Doulting Beds" entered in the column headed "Remarks."

Considerable accuracy may be claimed for the lists of fossils given. Mr. S. S. Buckman, F.G.S., identified the Ammonites; Mr. W. H. Hudleston, F.R.S., most of the Gasteropods; Mr. W. D. Lang the Corals and Bryozoa; and Mr. E. T. Paris the Echinoids.

To the north-east of Doulting the Inferior Oolite is in many places in actual contact with the Palæozoic rocks of the Mendip Hills. But traced away from those hills Liassic beds are seen to come in below them, and there is very soon the normal formational sequence of, Inferior Oolite, Upper, Middle, and Lower Lias, with the Rhætic and Keuper below.

The Marlstone or rock-bed of the Middle Lias is very well exposed in an abandoned quarry on Mays (or probably more correctly "Maes") Down, a mile and a half to the south of Doulting. Above are seen the basement-beds of the Upper Lias—clays and thin limestone-bands—which are also exposed on the slope of Small Down, below the "ancient entrenchment." Deposits of *falciferi* and *bifrontis* hemeræ are in evidence; then comes clay. How thick this clay is it is difficult to say, but there appear to be "Sands" also present in the hillsides. In the railway-cutting at Doulting Bridge a clay-bed comes immediately below the Inferior Oolite. Probably it overlies some sand, and—if it could be traced further east—might be seen to be succeeded by sand. Its date, however, is difficult to determine, but it is probably either *striatuli* or *Struckmanni*.[1]

Above the Upper Lias exposed in the railway-cutting comes the Inferior Oolite. In this neighbourhood it is divisible as follows:—

	Subdivisions.	*Approximate thicknesses in feet.*	
Doulting Beds.	i.—Rubbly-Beds; *Terebratula globata*, auctt., *non* Sowerby, common, etc.	8	= *Clypeus*-Grit.
	ii.—*Anabacia*-Limestones	8½	
	iii.—Doulting Stone; massive Freestone ...	44	
	[Upper Coral-Bed and Dundry Freestone wanting.]		
	vi.—"Conglomerate-Bed" [Upper *Trigonia*-Grit].	1½	= Upper *Trigonia*-Grit.

There can be no doubt that the Conglomerate-Bed finds its equivalent in the similarly-designated deposit at Maes Knoll, Dundry Hill, near Bristol, where there is evidence that it is succeeded by the Dundry

[1] At first I thought the clay-bed might come below the *Striatulum*-Bed, making it pre-*striatuli*, but then an alternative explanation suggested itself, which was graphically represented on p. 392 of my main paper. Unfortunately, however, the statement of the earlier view (lines 15–17 from bottom of p. 391) escaped the necessary qualification.

Freestone.[1] The Upper Coral-Beds succeed the latter at the quarry near the Church, and then—as is known from the evidence of many sections—follows the Doulting Stone. But in the neighbourhood of Doulting the Doulting Stone succeeds the Conglomerate-Bed at once, without the intervention of any Dundry Freestone or Upper Coral-Bed: there is a non-sequence. The Doulting Stone includes the celebrated Doulting Freestone—a stone well-known in building-circles. On the whole the limestones of the Doulting-Stone subdivision are of fairly uniform aspect and not conspicuously fossiliferous. Fossils can, however, be obtained by diligent search, and it is worthy of record that near the top is a circular variety of *Pecten demissus*, Phillips, which occurs on precisely the same stratigraphical horizon in the local *Clypeus*-Grit of the Horton-Rectory Quarry in the South Cotteswolds, to which the Doulting Stone is the equivalent. The *Anabacia*-Limestones are typically very distinct from the underlying Doulting Stone and overlying Rubbly-Beds. The Rubbly-Beds are the most fossiliferous of the Inferior-Oolite strata in the neighbourhood. Sometimes they are not so definitely marked off from the *Anabacia*-Limestones, and when such is the case it is rather difficult, if a fossil is not found *in situ*, to say from which it came. If there is any matrix adhering it will generally be found that on fossils from the *Anabacia*-Limestones the matrix is of a white colour, while on those from the Rubbly-Beds it is distinctly browner, and there are few oolite-granules.

During a number of visits to Doulting, made since my main paper was published, particular attention was paid to the occurrence of ammonites in the upper portion of the Doulting Beds and Fullers' Earth, with a view to the more precise dating of these deposits.

There are now about 12 feet of Fullers' Earth exposed at the Farmcombe Quarry, and the little oyster identified with *Ostrea Knorri*, Voltz, occurs in the lowest portion immediately above the "limestone, rubbly, white, mixed with clay; variable, say 1 foot" (Quart. Journ. Geol. Soc., 1907, vol. lxiii, p. 395). From this bed has been obtained a fragment of an ammonite that is probably *Zigzagiceras clausiprocerum* (S. S. Buckman); and either from the same bed or the top of the Rubbly-Beds a fragment of "? *Parkinsonia lævis* (Quenstedt)." So the basement-portion of the Fullers' Earth may be of *zigzag* hemera, and the *Knorri*-Clays of approximately the same date.

The *Aulacothyris doultingensis*, Richardson, MS., is closely allied to the form from the "Marl-Bed" (*Garantiana*) of Stoford, Somerset, which has been recorded as *Aulacothyris "Meriani*, var."[2] It does not appear desirable to describe either this or the new *Velopecten* in this paper, but to await one devoted entirely to the description of some new Inferior-Oolite fossils.

[1] The statement in my main paper (p. 420)—"but how thick it was, or whether it rests directly upon the 'grit,' or was separated therefrom by the Upper Coral-Bed . . . "—was inadvertently transcribed from notes made before I had satisfied myself about the correct position of the Upper Coral-Bed and should be erased.

[2] Quart. Journ. Geol. Soc., 1893, vol. xlix, p. 484.

List of Inferior-Oolite Fossils in the John-Phyllis Collection from Doulting, Somerset.

Species.	Conglomerate-Bed.	Doulting Stone.	*Anabacia*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
II. CŒLENTERATA.						
ii. CNIDARIA.						
1. Anthozoa.						
Anabacia complanata (Defrance)	–	*	*	*	–	Common.
Dimorphorœa sp.	–	–	–	–	–	Doulting Beds. Numerous pieces said to be from Doulting.
? *Isastræa limitata*, Lamouroux	–	*				
? — *microphylla*, Tomes	–	*				
Montlivaltia delabechei (Edwards & Haime).	*	–	–	–	–	
— *lens*, Edwards & Haime	–	–	–	–	–	Doulting Beds.
— *numismalis* (d'Orbigny)	–	–	–	*	–	
— cf. *trochoides*, Edwards & Haime	–	–	–	–	–	Said to be from Doulting.
— sp.	–	–	–	*	–	
— sp.	–	–	–	–	*	Common at Farmcombe Quarry.
— sp.	–	–	–	–	?	
Thecosmilia ? sp.	–	–	–	?	–	
2. Hydrozoa.						
Acanthopora spinosa (Lamouroux)	–	–	–	–	–	Doulting Beds. Common.
III. ECHINODERMATA.						
iii. ECHINOZOA.						
1. Echinoidea.						
Acrosalenia spinosa, Agassiz	–	*	–	*	–	Common.
Clypeus Hugi, Agassiz	–	–	–	*	–	Doulting-Bridge Quarry.
Collyrites ovalis (Leske)	–	*	–	–	–	Typical form.
— aff. *ovalis* (Leske)	–	–	–	–	*	Not so oval as the typical form.
Echinobrissus clunicularis (Lhwyd)	–	*	–	–	–	
Holectypus depressus (Leske)	–	–	–	*	–	Common.
— *hemisphæricus*, Agassiz	–	–	–	*	–	
Stomechinus ? *bigranularis* (Lamarck)	–	–	–	*	–	One immature specimen.
IV. VERMES.						
5. Annelida.						
Serpula convoluta, Goldfuss	–	–	–	–	–	Doulting Beds.
— *deplexa*, Bean	–	–	–	?	–	Large variety similar to that occurring in the Pea-Grit. Lower *Trigonia*-, and *Buckmani*-Grits of the Cotteswold Hills and the Millepore Limestone of Yorkshire.
— *deplexa*, Bean	*	–	–	–	–	Small variety similar to that in the "Marl-Bed" (*Gardinianus*) of Bradford Abbas.

Species.	Conglomerate-Bed.	Doulting Stone.	*Aundacia*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
Serpula cf. *trochleata*, Goldfuss . .	*	–	–	–	–	Same form occurs in the "Marl-Bed" of Bradford Abbas, and the Upper *Trigonia*-Grit of the Cotteswold Hills.
— spp.	–	*	–	*	–	Including forms 1 and 2.
Vermilia quinquangularis (Goldfuss)	–	–	–	*	*	
MOLLUSCOIDEA.						
1. Bryozoa.						
Ceriopora sp.	–	–	–	–	–	Doulting Beds.
Diastopora Michelini (Blainville) .	–	–	–	*	–	
Heteropora conifera (Lamouroux) .	–	–	–	–	–	Doulting Beds. Common.
Spiropora annulosa, Michelin . . .	–	–	–	–	–	,, ,,
2. Brachiopoda.						
Acanthothyris doultingensis, Richardson & Walker.	–	–	–	–	*	
— *midfordensis*, Richardson & Walker.	–	–	–	–	*	
— *spinosa* (Schlotheim)	–	?	–	*	–	
Aulacothyris carinata (Lamarck) .	–	–	–	–	*	
— *Mandelslohi* (Oppel)	–	–	–	–	*	
— *doultingensis*, Richardson, MS.	–	–	–	–	–	
Dictyothyris Marieri (Davidson) . .	?	–	–	–	–	Precise horizon doubtful, but probably it came from the Conglomerate-Bed. This specimen, found by Phyllis, is in the British Museum.
Ornithella cadomensis (E. Deslongchamps).	–	–	–	–	*	Fullers'-Earth Rock, (? near) Doulting.
— *ornithocephala* (Sowerby) . .	–	–	–	–	*	Fullers'-Earth Rock, (? near) Doulting.
Rhynchonella plateia, Richardson & Walker.	–	–	–	–	*	Rare.
— *Smithi*, Walker	–	–	–	–	*	
— aff. *subdecorata*, Davidson . .	?	–	–	–	–	? *Scissi*: remanié in the Conglomerate-Bed.
— *subtetrahedra*, Davidson . . .	–	–	–	*	–	
— 3 spp.	–	–	–	–	–	Doulting Beds. [Forms 1, 2, and 3, L. R.]
Eudesia cf. *cardium* (Lamarck) . .	–	?	–	–	–	Doulting Beds. Rare.
Terebratula globata, Sowerby, *non* auctt.	–	–	–	–	*	Fullers'-Earth Rock, (? near) Doulting.
— *globata*, auctt., *non* Sowerby .	–	–	–	*	*	Common.
— *doultingensis*, Richardson & Walker.	–	–	–	–	*	
— *sphæroidalis*, Sowerby . . .	–	–	–	–	*	Immature.
— (nearest to) *sphæroidalis*, Sowerby.	–	–	–	–	*	Umbo of dorsal valve not sufficiently flat.
Zeilleria emarginata (Sowerby) . .	–	–	–	–	*	Very rare.

Species.	Conglomerate-Bed.	Doulting Stone.	*Anabacia*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
VI. MOLLUSCA.						
1. Pelecypoda.						
Alectryonia gregaria, auctt.	–	–	–	*	–	
? *Cardium citrinoideum*, Phillips	–	–	–	*	–	
Ceromya plicata, Agassiz	–	–	–	?	–	Same size as specimen figured in Monogr. Great Oolite Mollusca, Pal. Soc., pt. 2 (1853–4), pl. x, figs. 1*a* and *b*.
Corbis (*Corbicella*) *complanata*, Lycett	–	–	–	*	–	
Cypricardia ? cordiformis, Deshayes	–	*	–	–	–	
— aff. *rostrata* (Sowerby)	–	–	–	*	–	The casts of the umbones are more slender and prominent than the *Phillipsiana-Bourguetia*-Bed fossils figured by Morris & Lycett, Monogr. Great Oolite Mollusca, pl. vii, fig. 9.
Goniomya anguilifera (Sowerby)	–	–	–	–	*	Fullers'-Earth Rock, (? near) Doulting.
Gresslya abducta (Phillips)	–	–	–	*	–	
Homomya gibbosa (Sowerby)	–	–	–	*	–	Typical form.
Isocardia minima, Sowerby	–	–	–	*	–	
Limatula gibbosa (Sowerby)	–	–	–	*	–	Typical form.
Limea duplicata (Sowerby)	–	*	–	–	–	Same form as in the Cotteswold Hills.
Lithophagus inclusus (Phillips)	–	*	*	*	–	
Lucina rotundata (Römer)	–	–	–	?	–	
— ? *crassa*, Sowerby	–	–	–	*	–	Internal cast.
Myoconcha implana, Whidborne	–	?	–	–	–	
Ostrea acuminata, Sowerby	–	–	–	–	?	Several specimens apparently from the Fullers' Earth.
— cf. *acuminata*, Sowerby	–	–	–	*	–	More convex than the above.
— *costata*, auctt.	–	–	–	*	–	Common.
— *gregaria*, auctt.	–	–	–	*	–	
— *Knorri*, Voltz	–	–	–	–	*	Common.
— *sandalina*, Goldfuss	–	–	–	*	–	
— spp.	–	–	–	*	*	Several species not yet identified.
Pecten (*Chlamys*) *articulatus*, Schlotheim.	–	–	–	–	?	Near to base of Fullers' Earth or top of Rubbly-Beds.
— (*Camptonectes*) *arcuatus*, Sowerby.	–	–	–	*	–	
— (*Syncyclonema*) *demissus*, Phillips	–	–	–	*	*	Nearest to this form.
— of the *Pecten-vagans*-group	–	–	–	*	–	
Pholadomya aff. *Heraulti*, Agassiz	–	–	–	–	*	
— aff. *fidicula*, Sowerby	–	–	–	?	–	The same species as occurs in the *Clypeus*-Grit of the Cotteswold Hills.
— ? *spatiosa*, Whidborne	–	–	–	*	–	
Pinna aff. *cuneata*, Phillips	–	–	–	*	–	Not quite so flat as the form from the Lower *Trigonia*-Grit.

Species.	Conglomerate-Bed.	Doulting Stone.	*Anabacia*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
Pleuromya decurtata (Goldfuss, *non* Phillips).	–	–	–	*	–	*Vide* Chapuis & Dewâlque, "Description des Fossiles des Terrains Secondaires de la Province de Luxembourg," pl. xxi, fig. 8.
— *Goldfussi* (Lycett)	–	–	–	*	–	
Pseudomonotis echinata (Sowerby)	–	–	–	–	–	Doulting Beds.
Posidonomya opalina, Quenstedt	–	–	–	*	–	Rare.
? *Protocardia clypeata* (Witchell)	–	*	–	*	–	Internal casts.
Pteria (*Oxytoma*) *costata* (Sowerby)	–	–	–	*	–	
— cf. *inæquivalvis* (Sowerby)	–	–	–	–	–	Doulting Beds.
— *digitata* (Deslongchamps)	–	–	–	–	–	"
— *Münsteri* (Goldfuss)	–	–	–	–	*	"
Trigonia costata, Sowerby	–	–	–	?	–	*Vide* "British Fossil *Trigoniæ*," Pal. Soc., 1872–9.
— *costata*, Sowerby	–	–	–	?	–	Similar to the specimen figured in pl. xxix, fig. 5.
— cf. *pullus*, Lycett, *non* Sowerby	–	–	–	–	–	Similar to the specimen figured in pl. xxxiv, fig. 9. Doulting Beds.
— 2 spp.	–	*	–	–	–	Internal casts.
Velopecten doultingensis, Richardson, MS.	–	–	*	–	–	
Volsella cuneata (Sowerby)	–	–	–	–	–	Doulting Beds.
— *gibbosa* (Sowerby)	–	–	–	*	–	Typical form.
4. Gasteropoda.						
Actæonina antiqua, Lycett	–	–	–	*	–	Same as at Rodborough Hill, Stroud.
— *gigantea* (Deslongchamps)	–	–	–	*	–	Same as at Rodborough Hill, Stroud.
— aff. *gigantea* (Deslongchamps)	–	–	–	*	–	Cf. fig. 3, pl. xliii, of W. H. Hudleston's "Gasteropoda of the Inferior Oolite," Mon. Pal. Soc.
— aff. *gigantea* (Deslongchamps)	–	–	–	*	–	Cf. fig. 2, pl. xliii, and fig. 3. Less truncated base than the specimen depicted in the former figure, and less acute spire than that in the latter.
— aff. *gigantea* (Deslongchamps)	–	–	–	*	–	Short variety; more abbreviated than that figured by Hudleston, fig. 2, pl. xlii, measuring 10 mm. across the widest part and only 10·5 in length along the body-whorl.
Alaria sp.	–	?	–	–	–	
Amberleya Orbignyana, Hudleston	–	–	–	*	–	
— sp. indet.	–	–	–	*	–	
Ataphrus Labadyei (d'Archiac)	–	–	–	*	–	

Species.	Conglomerate-Bed.	Doulting Stone.	*Anabacia*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
Ataphrus lævigata (Sowerby)	–	–	–	*	–	
Bourguetia striata (Sowerby)	–	–	–	*	–	Indistinguishable from the small forms from the *Bourguetia*-Beds of Cleeve Hill, near Cheltenham.
Cerithinella sp.	–	–	–	–	–	Doulting Beds.
? *Cerithium* sp. indet.	–	–	*	–	–	Internal cast.
Euspira cf. *canaliculata*, Morris & Lycett.	–	–	–	–	–	A megalomorph. Too high a spire for the true *E. canaliculata*. Doulting Beds.
Natica bajociensis, d'Orbigny	–	–	–	*	–	Common.
— *Hulliana*, Lycett	–	–	–	*	–	
— *Zelima*, d'Orbigny	–	*	–	*	–	? = *N. dundricusis*, Tawney.
— spp.	–	–	–	–	–	Immature. Doulting Beds.
— sp.	–	–	–	–	*	
Pleurotomaria armata, Munster	–	–	* or *		–	
— ? *elongata* (Sowerby)	–	–	–	–	–	Doulting Beds.
— ? *granulata* (Sowerby)	–	–	–	–	–	,,
— ? *fasciata* (Sowerby)	–	–	* or *		–	2 spp. of the *P.-fasciata*-Group.
— ? *ornata-depressa*, Hudleston	–	–	–	*	–	Closely allied to a form from the Upper Coral-Bed of Worgan's Quarry, near Stroud.
— sp.	–	–	* or *		–	
— sp.	–	–	–	*	–	
Pseudomelania cf. *astonensis*, Hudleston.	–	–	–	–	–	Doulting Beds.
— *lineata* (Sowerby)	–	–	–	*	–	Or *P. lineata* (Sowerby).
— *procera* (Deslongchamps)	–	–	* or *		–	Doulting Beds.
Solarium subvaricosum, Hudleston	–	–	–	–	–	,,
— sp. indet.	–	–	–	–	–	
Straparollus sp. indet.	–	–	–	*	–	
Trochus duplicatus, Sowerby	–	–	–	–	–	"Inferior Oolite, Doulting."
5. Cephalopoda.						
Nautilus cf. *burtonensis*, Foord & Crick.	–	–	–	–	–	Doulting Beds. Worn specimens.
Cadomites aff. *Deslongchampsi* (d'Orbigny).	?	–	–	–	–	*Niortensis* hemera. Very rare indeed. Said to be from Doulting. ? remanié in the Conglomerate-Bed.
Morphoceras aff. *polymorphum* (d'Orbigny).	–	–	–	–	–	"Interior Oolite, Doulting."
Oppelia aff. *subradiata* (Sowerby)	*	–	–	–	–	*Niortensis*: remanié.
Otoites Sauzei (d'Orbigny)	–	–	–	–	–	*Sauzei*, (? near) Doulting.
Parkinsonia ? *lævis* (Quenstedt)	–	–	–	–	*	
Perisphinctes aff. *Davidsoni*, S. Buckman.	*	–	–	–	–	*Niortensis* or *Garantianæ*.
— aff. *funatus* (Oppel) and						
— *pseudofrequens* (Siemiradzki)	*	–	–	–	–	*Garantianæ*.

Species.	Conglomerate-Bed.	Doulting Stone.	*Acuticosta*-Limestones.	Rubbly-Beds.	Fullers' Earth.	Remarks.
Stepheoceras cf. *macrum* (Quenstedt) and *bayleanum* (Oppel).	–	–	–	–	–	*Sauzei*, "Inferior Oolite, Doulting."
— aff. *pyritum* (Quenstedt) . . .	*	–	–	–	–	Remanié from *Blagdeni*.
— aff. *umbilicus* (Quenstedt) . .	*	–	–	–	–	" "
Belemnites (*Belemnopsis*) *aripistillum*, Lhwyd.	–	–	–	–	*	
— (*B.*) *bessinus*, d'Orbigny . . .	–	–	–	–	*	
VI. ARTHROPODA.						
i. BRANCHIATA.						
1. Crustacea.						
Eryma sp.	–	[* D. B.]			–	19 pieces: mostly the fixed ultimate joints. D. B. = Doulting Beds.
VIII. VERTEBRATA.						
1. Pisces.						
Hybodus sp.	–	[?* D. B.]			–	1. Tooth.
Lepidotus sp.	–	–	–	[*]	–	1. Scale. Ident. Dr. A. Smith Woodward.
Strophodus magnus, Agassiz . . .	–	[* D. B.]			–	Common.
3. Reptilia.						
Ichthyosaurus sp.	–	[?* D. B.]			–	1. Vertebra from the tail. Said to be from the Inferior Oolite of Doulting.

It is hoped that the specimens listed above, now that they have been subjected to a careful revision, will be useful to students of the Inferior Oolite and Fullers' Earth of the neighbourhood of Doulting. Of course there are gaps, but before long it is probable that many of them will be made good. The examination of the collection has emphasized the correctness of the correlation of the Doulting Beds with the *Clypeus*-Grit of the Mid-Cotteswolds, the majority of the fossils being identical in form and appearance.

Among the ammonites are specimens indicative of *Sauzei*, *Blagdeni*, and *niortensis* hemeræ, as well as *Garantianæ*. The Conglomerate-Bed, of course, is of *Garantianæ* hemera, and there is little doubt—judging by the matrices of some of the specimens—that some of the ammonites indicative of *Blagdeni* and *niortensis* hemeræ were remanié in it—those indicative of *niortensis* in particular. But the same cannot be said about the *Otoites Sauzei*. Leaving this out of consideration, what the ammonites seem to indicate is the destruction of at least deposits of *Blagdeni* and *niortensis* dates during the "Bajocian Denudation."

VI.—The Mechanics of Overthrusts.

By T. Mellard Reade, C.E., F.G.S.

IN attempts to unravel some of the weightier problems of geology it has lately been assumed that certain discordances of stratification are due to the thrusting of old rocks over those of a later geological age. Without in any way suggesting that the geology has in any particular instance been misread, I should like to point out the difficulties in accepting the explanation looked at from a dynamical point of view when applied on a scale that seems to ignore mechanical probabilities. Some of the enormous overthrusts postulated are estimated at figures approaching 100 miles. Have the authors considered that this means the movement of a solid block of rock or rocks of unknown length and thickness 100 miles over the underlying complex of newer rocks? If such a movement has ever taken place, would it not require an incalculable force to thrust the upper block over the lower, even with a clean fractured bed to move upon? Assuming that the block to be moved is the same length as the overthrust, the fracture-plane would in area be $100 \times 100 = 10{,}000$ miles. I venture to think that no force applied in any of the mechanical ways known to us in Nature would move such a mass, be it ever so adjusted in thickness to the purpose, even if supplemented with a lubricant generously applied to the thrust-plane. These are the thoughts that naturally occur to me, but as my mind is quite open to receive new ideas I shall be glad to know in what way the reasoning can be met by other thinkers.

REVIEWS.

I.—Memoirs of the Geological Survey of England and Wales.

The Coals of South Wales, with special reference to the Origin and Distribution of Anthracite. By Aubrey Strahan, M.A., Sc.D., F.R.S., F.G.S., and W. Pollard, M.A., D.Sc., F.G.S.; assisted by E. G. Radley. pp. v, 74, with 10 folding plates. London: printed for H.M. Stationery Office, 1908. Price 1*s.* 6*d.*

THIS memoir includes a chapter entitled "Historical and Introductory," which deals with previous knowledge of the occurrence and distribution of anthracite in South Wales, and states certain facts as to the distribution of anthracite and its passage into other forms of coal. "The changes undergone by the coal present certain stages . . . from House Coal, or the most bituminous, the change is gradual into Steam Coal, and from Steam Coal into Anthracite."

We are told that the "Anthracitic regions lie in the north-western corner of the Carmarthenshire, Brecknock, and Glamorganshire field and in Pembrokeshire," and "Lines of equal anthracitisation circle round an area which extends from Kidwelly to Glyn Neath. In Pembrokeshire all the coal is anthracitic."

The second generalization states that "the seams all show the change on approaching the anthracitic region, but the higher seams

show it later than the lower," and a third that "the loss of bituminous matter takes place at a more rapid rate in a south to north direction than in an east to west direction."

A very complete and carefully carried out series of analyses have been made of coal methodically collected for that purpose, the results of which, with details of the methods employed, occupy a large part of the memoir.

Chapter ii, on the sequence of the seams, is short and unsatisfying. No reasons are given for the individual correlation of seams, and palæontological methods might have been unknown. The idea of an appeal to fossils, either plants or shells, does not seem to have occurred to the author, although in other coalfields excellent results have been obtained.

Chapters iii–viii deal with statistics and the explanation of the plates, and the memoir closes with a chapter on the "Origin of Anthracite." Here previous views are discussed, and the theory is adopted that "the differences between anthracitic and bituminous coals of South Wales are mainly due to original differences in deposition," for the following reasons:—

1. The seams are not all similarly anthracitic; though each seam is generally more anthracitic than the one above it, there are many exceptions to this rule.

2. The anthracitic character was not due to faults, but existed before the faults were formed.

3. The anthracite existed as such before the coalfield was reduced by denudation to its present dimensions.

4. The percentage of ash diminishes *pari passu* with the decrease of bituminous matter.

It must be confessed that the conclusion leaves the question in an unsatisfactory condition, and no details of what may have been the difference in deposition are suggested; therefore the *vera causa* of anthracitization is still to be discovered. The question in the present volume has been attacked only from the chemical side, and it would be interesting to know whether the microscope would have revealed any structural or biological changes in the seams of coal. A good and adequate index completes the volume.

W. H.

II.—The Rhodesian Miner's Handbook. By F. P. Mennell, F.G.S. pp. x + 143. Bulawayo: Ellis Allen, 1908. Price 5*s*.

THIS valuable handbook forms publication No. 4 issued by the Rhodesia Museum, of which institution the author has been for the past six years the curator. Of its extreme usefulness to the prospector in Rhodesia there can be no question, and he will save himself much waste of time, and possibly bitter disappointment, if he takes care to include it in his outfit. The book teems with invaluable information relating to the ores of commercial importance, the type of rock in which they may most probably be found, the identification of the principal mineral species, the testing of the quality of a lode, the steps to be taken to establish a title to a mine,

the proper method of working one, and so on. It, however, by no means consists of a series of working notes briefly and badly set down, but opens with a short, yet sufficiently general, account of geological formation and the origin of ore which will enable the miner who has had no previous geological training to appreciate the disposition of lodes and the natural processes that have brought them about. The general reader, moreover, will be interested in the statistical accounts of the mineral resources of the country which are incidentally given; there seems no doubt that, despite a somewhat chequered career in the past, the mineral industry of Rhodesia has a great future to be realised when the country has been opened up and the railway facilities fully developed.

After the general discussion referred to, chapters follow which deal with the metals, precious and base, and the minerals containing them, precious stones, and coal. It may surprise many to find that Rhodesia already ranks as one of the great gold-producing countries of the world, and may in the near future challenge the position held by the Transvaal. The account of the methods used by the natives in ancient times for crushing and concentrating the ores shows how little in principle the system of working has altered. The section dealing with zinc includes a description of the remarkable mineral occurrence at the new Broken Hill mines which has attracted so much attention among mineralogists. The Somabula gem-district appears to be prolific in all kinds of precious stones, especially diamond, chrysoberyl, and topaz, the last of a peculiar pale-blue colour. Rhodesia is fortunate in possessing an ample coal supply, which will be of increasing importance as time goes by and local manufactures spring up.

The book is well printed and enriched by a large number of excellent illustrations, mostly reproduced from photographs.

III.—Rocks and Rock Minerals. A Manual of the Elements of Petrology without the use of the Microscope. By Louis V. Pirsson. pp. 414 + vi, with 74 figures in the text and 36 plates. New York, John Wiley & Sons; London, Chapman & Hall, 1908.

So great was the impetus imparted to the development of petrological science by the introduction of the use of the polarising microscope that all modern textbooks dealing with the study of rocks consider the subject from the microscopical point of view. Yet there has long been felt the need for a book that should enable an observer by the aid of a pocket-lens and the application of a few simple tests, which can readily be carried out even in the field, to identify with sufficient accuracy for practical purposes any rock that may be met with. Thus the engineer and the architect are anxious to learn whether some particular rock is characterised by strength and durability, and are not concerned with the minutiæ of petrology. There can be little doubt that Professor Pirsson's manual will be in great demand; of the excellence of the work his name alone is sufficient guarantee, and he has had the teaching experience requisite for gauging the type of book wanted.

The author divides the book into three principal parts. In the first he gives useful hints as to the most suitable course of study, and includes a description of the simple apparatus and reagents required. A brief discussion follows on the nature of the interior of the Earth and the character of its crust, and some of the differing hypotheses that have been put forward. The second part is occupied with the minerals that are of importance in the formation of rocks. The author commences by rehearsing the physical and chemical properties which admit of ready determination, and proceeds to describe concisely the characters of the important species, grouped together as silicates and oxides, hydrous silicates, carbonates, and sulphates. In the next chapter he gives some simple chemical tests, such as need no elaborate apparatus, and the part ends with two valuable tables for the identification of minerals: the first, which is based upon the most obvious physical characters, such as cleavage, streak, transparency, and hardness, and comprises about thirty species, is intended for use in the field; while the second, which is based in addition upon the ordinary blow-pipe reactions, and includes about fifty species, should preferably be employed whenever the additional tests can be made. The third and last is the main part of the book, and, indeed, fills two-thirds of the total number of pages. It is occupied with a full description of the various kinds of rocks, divided into the three great groups, igneous, stratified, and metamorphic rocks, and with a discussion of their classification. For each rock the author gives the composition, properties, occurrence, uses, and relation to other rocks, and at the end adds a useful table for the determination of rocks from their most obvious characters. A copious index, in which the names of rocks are italicised, brings the book to a close.

Mention must not be omitted of the numerous admirable illustrations which add so much to the value of the book. The reproductions from photographs have been printed as plates, and are exceptionally clear and distinct.

G. F. H. S.

IV.—Egypt.

The Topography and Geology of the District between Cairo and Suez. By Thomas Barron. 8vo; pp. 133; maps and plates. Cairo (Survey Department), 1907.

THIS fine memoir has been printed just as it left the hands of its lamented author. Opening with a chapter on the topography of the region, full of interesting matter on meteorology and water supply, vegetation and zoology, botany and inhabitants, the author describes the Pleistocene, Miocene, Oligocene, Eocene, and Cretaceous beds, their fossils, etc. The basaltic flows, necks, and sheets are dealt with in chapter vii, and are recognised as Oligocene and of the same age as those seen south-west of the Giza Pyramids. The faults and folds of the area are fully described in chapter ix, one of 55 metres and another of 165 metres being especially mentioned. The final chapter (x) deals with the relief of the ground, and discusses at length the denudation, agents of sculpture, sand action, sand-blast,

three-angled stones, and other matters of interest. Dr. Barron considers that the direction of the wind, *not* the prevailing wind, causes the erosion, and agrees with Dr. Vaughan Cornish, but differs from the majority of writers on the subject. He compares this locality with the Libyan Desert, and finds that in both areas the sand-carrying wind comes from the south-west, while the prevailing wind comes from the N.N.W. And this is shown by the orientation of the sand-dunes, the planed-down surfaces of the rocks, and the direction of the long slope of the dunes. An excellent index has been provided by those who have so carefully seen our lamented friend's manuscript through the press.

V.—Granite and Gneiss.

Sederholm (J. J.): On Granite and Gneiss, their Origin, Relations, and Occurrence in the Pre-Cambrian Complex of Fenno-Scandia. Bull. Comm. géol. Finlande, No. 23, Helsingfors, 1907.

THIS is a long summary in English of a paper in Swedish in which the author shows, through the investigation of the schists of Finland, that rocks occur in these masses showing every sign of having been formed by the same slow processes of sedimentation as younger strata, or by true volcanic action, but differing as to its intensity, or the conditions under which the magma solidified, from that of later times. These pre-Cambrian sediments have been traced throughout the whole eastern portion of Fenno-Scandia, and analogous rocks have been found in the western area of the region. Finnish geologists have also traced these pre-Cambrian beds progressively downwards in a geological sense, and backward in time until they have apparently reached the bed-rocks of this ancient area. Ascertaining the probable origin of any rock-mass in the region, their relative ages have been determined by studying the contact-relations to each other, especially with regard to those granitic masses which have the widest extension. The relations of the different rocks to the great orogenetic movements which have affected the region, and have impressed upon the rocks their widely differing secondary characters, have also been observed. From all this the author has evolved a classification which seems to him to hold good for a great part of Fenno-Scandia. Descriptions and illustrations of all these rocks are given, as well as a geological map of 1 : 8,000,000 showing their distribution.

VI.—Geological Literature for 1907.

ONCE more it is our pleasing duty to call the attention of geologists to the "Geological Literature added to the Geological Society's Library during the year ended December 31st." This remarkable work, compiled entirely by Mr. William Rupert Jones, and edited by Mr. L. L. Belinfante, has now reached its fourteenth year. It consists of 120 pages of author titles, thus listing about 3,000 items, and an index to their contents of 90 pages, which index includes a number of maps not placed among the author titles. It is compiled by one who is thoroughly conversant with his subject in all its varied

branches. Whether geologist, palæontologist, mineralogist, petrologist, or mining expert, no one who pretends to do any work can afford to be without this publication, which, despite the faults of omission or commission usual in any work of the kind, is far and away the most valuable of any geological bibliography offered to the public.

The singular thing is that it should still remain unknown to many at home and abroad, for its low price (2*s.*) places it within reach of all. But as no attempt is made by the Society to advertise its existence, perhaps this is not to be wondered at. Some people seem to think that it is limited in its scope to those items received by the Geological Society; so it is, but the Society receives over 80 per cent. of the publications on the sciences it includes. The extraordinary value of the book lies in its index. Take one entry—"C. Reid, on the Geology of the country round Newquay, Mem. Geol. Survey, 1907." This is indexed under no less than fourteen heads, so that practically the whole contents of the memoir can be picked up under any special item. The same minuteness of indexing applies to the foreign literature.

It is undoubtedly the most valuable publication issued by the Geological Society of London, and will remain a standard work of reference as long as any geologist worthy the name interests himself in the subject.

CORRESPONDENCE.

THE GAVARNIE PROBLEM.

Sir,—Having only now seen Mr. Dixon's sections and conclusions, I can supplement them from observations repeated during the present year.

On Mr. Dixon's map the essentially continuous sheet of Hippurite limestone is figured as absent over two spaces each a kilometre in extent, and definable as the most easily accessible from Gavarnie. One of these is concealed by talus, but that at the mouth of the Ossoue valley gave me, in 1894, the following results of field and microscopic observation, repeatedly verified since that date. The supposed break is merely an extremely metamorphosed portion of the visibly continuous Cretaceous. It is penetrated throughout by numerous veins and bosses of microgranulite, undeniably proceeding from the underlying granitic basis. M. Bresson first admitted it to be pinched Cretaceous, but is now compelled to describe it as Palæozoic "by analogy of facies and by the established data of the age of granite." This analogy and these data led the last Director of the French Survey to map the Hippurite limestone as Cambrian over half the Pyrenees, and to denounce my maps and observations as "*a priori* inexact." Even M. Carez, M. Lacroix, and M. L. Bertrand admit them to be baseless. But M. Bresson is similarly compelled to figure the Caprina Cenomanien as Aptien at Sarrencolin and the Ordovician at Bagneres de Bigorre as Permian, and to describe the Cambrian of Jacquot as a masterly definition of the Devonian, although it was

defined as *beneath* the Silurian and although its types were selected from the heart of the Cretaceous. As at the valley of Ossoue, so at every point where limestone occurs in the Archæan basis of Mr. Dixon, there is a visible synclinal descent of the Cretaceous into the said basis. At Eaux Chaudes the same Hippurite limestone descends into the granite basis at the valley of Bitet, and is similarly penetrated by microgranulite; being especially metamorphosed at contact with intrusions of Porphyry, termed Andesite and Labradorite on the map, which porphyry traverses the main granitic mass, and is itself traversed by a white granulite common at Gavarnie beside the synclines of Cretaceous. To Mr. Dixon's classification of the Gavarnie basis as Archæan I have no objection, provided that, with many geologists, I may interpret such Archæan as an imperfectly cooked example of a magma that is frankly eruptive at other points. Certainly around Gavarnie this magma was so plastic as to permit the descent of thin sheets of Cretaceous to three hundred yards in depth, and to exhibit, at visible points of contact, the most distinctive features of irruptive intrusion. Around Eaux Chaudes vast portions of the Hippurite limestone are converted into white crystalline marble, irregularly mixed with ferruginous and dolomitic segregations. Their irregularity forbids their attribution to those dynamic influences which Sauer and others have controverted in the Alps of Glarus, where *augen gneiss* is as irruptive as at Gavarnie. Finally, at the Ossoue valley and elsewhere around Gavarnie, I have traced the constant presence of the 'Permian' of Pinede, passing insensibly into a peculiar gneiss crammed with ferruginous concretions. M. Bresson admits its presence in his latest papers. In the Pinede valley it is eaten into by the homogeneous granite, and reduced in places to a conglomerate of granitic basis.

One other point may be recommended, without offence, to future observers. South of Gavarnie the Spanish plateau is composed, for many miles, of that Flysch which I introduced and defined in 1881 as that of the Vienna basin. Over a thickness exceeding 2,000 feet it exhibits the Helminthoids, composition, and very peculiar structure of that formation. Between Torla and Faulo it overlies the Danien as regularly as throughout the Spanish Pyrenees. The denial of the possibility of its post-Danien age, and the denial of its association with gypsum and salt, form the basis of the 200 pages of the latest French Survey Bulletin by M. Leon Bertrand. Yet in Spain, as in France, it presents characteristic Nummulites, which are ignored as deliberately as my Hippurites of Eaux Chaudes in 1885. In three papers of the Biarritz Association I have invited verification of the facts. The peculiarity of this formation is its alternation of tranquil and violently contorted portions, and its abundant evidence of local volcanic action. Some of these have been recently verified by Professor Fournier. But the formula "*a priori* inexact" has been more popular than observation, and is confirmed in Mr. Dixon's conviction that my references to current Palæontology have no connection with matters wholly decided thereby. On Mr. Dixon's own map the extent of the supposed 'thrust-plane' can be measured as 8 kilometres, yet he adds 2 kilometres in

favour of his theory and resorts to microscopic evidence in its difficulties. The popularity of this method of settling problems which concern the roots of all geological reasoning is assured, if only the exclusive discussion of authors whose decisive sections are totally erroneous by their own testimony can be persistently maintained.

P. W. Stuart-Menteath.

St. Jean de Luz.
September 15, 1908.

GLACIER GRAINS.

Sir,—I have pointed out[1] that in caves cut in the ice of glaciers, and also on the surfaces of glacier ice at high altitudes in places protected from the sun, the glacier grains are finely striated, the striations on different grains running in various directions. As each glacier grain is a distinct more or less strained crystal, it seemed advisable to determine whether the surface striations produced by evaporation bear any relationship to the crystalline structure of the ice grains.

Tyndall has pointed out that when, by means of a burning glass, the sun's rays are focussed in ice, liquid discs or flowers appear in the interior. These discs or flowers would, of course, be at right angles to the optic axis. I, therefore, last August, from the upper cave of the Rhone Glacier, cut samples of ice which showed these striations, and then by means of a burning glass produced the liquid discs within. In all cases these discs proved to be parallel with the external striations. One crystal in particular showed this very clearly. It was cut from a prism of ice and was striated on three sides. Not only were the striations on these faces in agreement, but the liquid discs produced by the sun's rays throughout the interior of the ice were in all cases in the same plane as the striations on the surfaces.

R. M. Deeley.

THE OCCURRENCE OF FLINTS IN AN OLD GRAVEL-BED NEAR NEWBIGGIN-BY-THE-SEA (NORTHUMBERLAND COAST).

Sir, — Some years ago I first found flints in this deposit. Previously their presence had been unknown, and, so far as I am aware, nothing has since been published concerning them. The gravel-bed is of pre-Glacial age and lies upon sandstone of the Coal-measures, the only available section being that exposed in the cliffs between Newbiggin and the mouth of the River Wansbeck. Here it may be traced for a distance of 480 feet. At its northern boundary it is seen to rest against an ancient cliff running in a direction normal to the present sea-front, and at this point the gravel is over 18 feet thick, the total height of the cliff being 22 feet.

[1] Geol. Mag., 1907, p. 529.

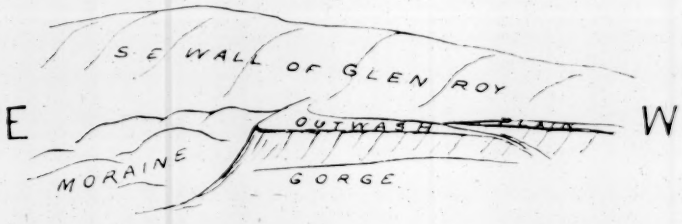
Southward the gravel thins out, until at a distance of 470 feet from the old cliff the section is only 1 foot thick. The bed consists of pebbles for the greater part, sandstones, porphyry, etc., of the neighbourhood. They are all well-rounded and water-worn. The flints are old chalk flints, usually broken and angular in form, occasionally flaked as if broken by impact with other stones, and sometimes red in colour. Their presence here seems to indicate the existence, somewhere in the bed of the North Sea, of Cretaceous deposits, probably derived from the Chalk formation which appears to have at one time existed in the North of Scotland, and of which the rounded, water-worn flints of Aberdeen are remains.[1]

R. G. A. Bullerwell, B.Sc.

Balgonie House,
Maddison Street, Blyth.
September 18, 1908.

A RECENT VISIT TO GLEN ROY, BY AN AMERICAN GEOLOGIST.

Sir,—In June last it was the writer's good fortune to visit Glen Roy with the excellent paper by Jamieson in his hand (Quart. Journ. Geol. Soc., 1892, vol. xlviii, pp. 5–37). It is a pleasure to confirm from observation the correctness of the conclusions reached by the author. It seems to the writer, however, that there are indications in the valley of a later chapter of glacial history, which, from enquiries, it is inferred has not yet been worked out, if it has indeed been noted. The object of this communication is to draw attention to the more clearly revealed facts in order that others who are nearer the locality may search for additional indications of this glacial episode.



The great glacial dam at the south base of Bohuntine Hill is clearly a terminal moraine laid down at the margin of the ice which proceeded from the Ben Nevis centre and impounded the drainage of the glen to produce one of the local lakes. There is, however, another heavy morainal obstruction in Glen Roy, situated just above the entrance to Glen Glaster, which affords the clearest evidence that the glacier

[1] [See the following:—(1) "On the Cretaceous Fossils from the Drift of Moreseat, Aberdeen," by G. Sharman & E. T. Newton, Geol. Mag., 1896, pp. 247–54, giving a list of fifty-three species belonging to the Lower Greensand, Gault, Upper Greensand, and to the Upper and Lower Chalk. (2) A second paper also in this Magazine for 1898, pp. 21–32, by A. J. Jukes-Browne & John Milne, giving a list of fifty-nine species, all from the Speeton Clay, Lower Greensand, Gault, and Upper Greensand, but none from the Chalk.—Ed. Geol. Mag.]

which deposited it entered the valley from a centre of dispersion to the eastward, and subsequent to the Lake period, the history of which Jamieson has so well cleared up.

The topography of this obstruction and its material are typical of terminal moraines, and what is most conclusive regarding its western frontage, there is an outwash apron which starts from its western margin and slopes gently away into the lower valley. This outwash plain has been cut away in a gorge subsequently eroded by the River Roy. The plain is, however, perfectly preserved on both sides of the valley, and seen from above was a conspicuous feature in the landscape at the time visited, because of a carpet of green, which contrasted sharply with the brown hue of the less fertile moraine and the valley walls.

It thus seems probable that the waning of the ice in the western mass around Ben Nevis was succeeded by an augmentation of the ice in the more eastern of the near-lying centres of dispersion.

Wm. H. Hobbs,
Professor of General and Dynamical Geology.

Department of Geology,
University of Michigan,
Ann Arbor, Michigan, U.S.A.
September 26, 1908.

OBITUARY.

CHARLES FREDERICK COCKBURN.

Born 1830. Died October 6, 1908.

Major-General C. F. Cockburn, R.A., joined the Army on December 19, 1849. He served in Canada, the Crimea (including the siege and fall of Sebastopol), Gibraltar, and Halifax (Nova Scotia). He was at the Royal Small Arms Factory, Solinger, Prussia, from 1859 to 1862, and was Assistant Superintendent at the Birmingham Factory for five years. He was the fifth generation of his family in the Army and the fourth in the Royal Artillery.

General Cockburn was an enthusiastic collector of fossils, especially from the Chalk, and immediately after the fall of Sebastopol employed any spare time he had in making a collection of Danian and other fossils from that region. His collection was described by W. H. Baily in the Quarterly Journal of the Geological Society, vol. xiv, 1858, and the types formerly in the Museum of Practical Geology are now in the British Museum. As this was one of the pioneer collections, its importance was such as to necessitate a visit from Dr. Karakasch only this year, and this geologist had the pleasure of meeting General Cockburn at Dover during his visit. Baily's paper was supplemented by a few pages of stratigraphical notes from the General's pen. During the years he collected, General Cockburn supplied many workers with valuable material from the Chalk, and